Appendix I. Gary Davis Memo June 26, 2003

Penny and Lane,

What's a Prototype Monitoring Program?

Recently I have heard several versions of why and how we came to have "prototype" monitoring programs in the National Park Service. Rarely do the current descriptions accurately reflect the records or my memories of the events that led to the prototype programs. In the interest in knowing our history so we don't have to repeat it too often, here's what I think happened.

National interest in long-term monitoring began to increase in the mid-1980s. SHEN and CHIS were independently finishing monitoring program designs. Alaska RD Boyd Evison, with support from WASO, convened a national group of scientists and managers to lay a foundation for science-based NPS stewardship. Boyd crafted a policy statement that committed the agency to long-term monitoring and indicated its purpose. The core of that statement was:
It is the policy of the National Park Service to:

- assemble baseline inventory data describing the natural resources under its stewardship
- monitor those resources forever to detect or predict changes that may require intervention, and
- provide reference points to which comparisons with other more altered parts of the home of man may be made

From that policy statement came a $600,000 annual commitment from WASO to explore how the National Park Service could inventory and monitor its resources. A steering committee was formed to develop program strategies. Based on experiences in SHEN and CHIS, we conservatively estimated the annual cost of a national monitoring program at approximately $200 million, 20% of existing ONPS funding, just for in-park operations. It was way more money than anyone was willing to request.

It was clear we needed to build more support for monitoring within the National Park Service, and among its partners. The committee adopted a two-step approach. First, build confidence that monitoring was effective and efficient. Then develop a few prototype programs in a step-wise fashion over ten years. Those prototype programs would show how ecological monitoring could be done and integrated into routine park operations. They were not designed to be research programs, but integral parts of park operations.

We launched three concurrent confidence-building activities: analyze experience, demonstrate competency (inventories), and conduct trials (prototype programs). First we analyzed previous experiences with long-term ecological data sets. This showed how long-term data were used to address major stewardship issues in national parks. The book *Science and Ecosystem Management in the National Parks,* published by the University of Arizona Press in 1996, presented 12 park-based case studies and documented the analysis.

The second activity was to demonstrate that the National Park Service knew what was in the parks. It was also to give every park something it needed. The National Park Service designated a dozen categories of basic resource inventories, and identified the tasks needed to complete and synthesize those inventories. We're now in the midst of that activity.

The prototype monitoring programs were most complicated and most expensive of the confidence-building activities the committee launched. Scientists and park managers committed to long-term monitoring still had serious questions about how to design and implement the programs. Most felt that monitoring approaches would be quite different in different ecosystems with various threats and stresses. Desert and fire ecologists were doubtful that the population/demographic approach adopted in eastern deciduous forests and Mediterranean coastal islands would work in western mountains or deserts. Organizational structures and administrative practices also varied across the country in different National Park Service regions, so people were concerned that a region-based program in one region wouldn't work in another that preferred park-based programs. Large parks and small parks also differed in their capacities to support science and technical staffs, which would influence monitoring program capacity and operations.

The prototype monitoring programs set out to test and evaluate these concerns by stratifying the National Park System into ten biomes. One prototype program was selected in each biome to test how scientific approaches might vary among biomes. The selections were also distributed across geographic regions to test effects of administrative variation. Two prototypes were designated to test the efficacy of networking small and medium sized parks to address park size issues. Proposals were solicited from all of the parks to compete in any of the categories. The proposals were peer reviewed. Selections were made to satisfy the design criteria (biomes, regions, and networks). The primary purposes of the prototypes were to evaluate the efficacy of monitoring and to determine how much variation emerged in independent monitoring design and implementation, both scientific and administrative. Eleven outstanding proposals were submitted. The rest were not very good. So 11 prototypes were selected, with two in the eastern deciduous forest biome, SHEN and GRSM.

The original plan was to fund four programs the first year, and add a program a year as funds from completed inventories became available. Only the first four prototypes were actually funded (CHIS, DENA, GRSM, and SHEN). After struggling for several years with funding and lack of support within the National Park Service, the implementation strategy was revised, accelerated, and evolved into the Natural Resource Challenge.

Each prototype was to develop a complete monitoring program for the park(s). While we expected that monitoring protocols developed for one park might be used with appropriate site-specific modifications in other parks, there was never an expectation that a coniferous forest prototype would develop only a protocol for conifers, or a coral reef prototype would design and test only coral monitoring protocols. The question was whether or not coniferous forest, coral reef, and desert ecosystems would dictate significantly different monitoring approaches, designs, and protocols for all of the elements in each park. After seeing >30 monitoring program design efforts now, it is clear to me that the same approach can work for all ecosystems. I don't know where or how the notion began that the National Park Service was developing a biome-specific protocol in each prototype program, with sample sizes of one in each biome, but it's now a common misperception and a source of reasonable curiosity and criticism.

Implementation of functional monitoring programs in parks is a noble cause. I'm glad you guys are engaged in making it happen. I hope these ramblings on the past help you in your endeavors.

Cheers, Gary

Gary E. Davis
Visiting Chief Scientist
Ocean Programs
U. S. National Park Service
Washington, DC 20005
(202) 513 7178 (805) 658 5707
Gary_Davis@nps.gov

Appendix II. Cabrillo National Monument Rocky Intertidal Monitoring Program Ten Year Performance Review (1990-1999) Summary Report & Statistical evaluation of the long-term Monitoring program of the Cabrillo National Monument

Report: June 2003
Reported By: Bonnie J. Becker, Marine Biologist (CABR)

I. Introduction

A. Purpose of Document

The purpose of this document is to summarize the results of the review of the first ten years of Cabrillo National Monument's rocky intertidal monitoring program. This document includes a general description of the activities of the statistical review and the review workshop that occurred in November 2001. Specific recommendations for program changes are compiled for consideration. Where appropriate, updates and changes that have been made between the workshop and the time of this report (June 2003) are included.

A report on the statistical analysis, conducted by Dr. Steven Schroeter, is given separately and supplements the information in this document (Appendix A).

B. Overview of Program

The Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP) was established in the spring of 1990 by Gary Davis (National Park Service [NPS]) and Dr. Jack Engle (University of California Santa Barbara [UCSB]). Davis and Engle modeled CRIMP as an extension of the prototype intertidal monitoring efforts that they began in the Channel Islands National Park (CHIS) during the 1980's. The CRIMP sites were to provide park-specific information, as well as serve as a comparison for the CHIS and other coastal Pacific sites.

CRIMP was conducted by Davis and Engle for the first six years of the program (Spring 1990 through Fall 1995). Beginning in 1996, funding and administration of the program was transferred to CABR, although a lack of funding led to a missed season in Spring 1996. Engle continued to assist with sampling, since the CABR Natural Resource Science Division was limited to a single staff member, Samantha Weber. Beginning in the fall of 1998, CABR hired a marine biologist, Bonnie Becker, who continues to administer the program. Due to the limited amount of park staff, CRIMP is and always has been a mostly volunteer effort. Since its inception, over 200 individuals have assisted in the effort. This volunteer aspect of the program is one of its strengths, since it serves education and outreach purposes as well as scientific and management ones. The tradeoff is a lack of expertise among its participants. The program was designed to be simple, so that well-trained volunteers and non-expert staff members with direction by a limited number of experienced staff could continue the effort in perpetuity.

As part of CRIMP, approximately one kilometer of rocky intertidal habitat within park administration was divided into three zones, representing existing patterns of human usage (Figure 1). Zone I is furthest north and contains the only public access point to the tidepools; it has consistently received the most visitation pressure. Zone II is central and receives an intermediate amount of usage. Traditionally, the southern Zone III has received the least visitation; it has been closed to the public since 1996. Within each zone, 33 fixed plots were established, for a total of 99 plots (Figure 2 - 5). Plots were chosen by determining the extent of habitat being utilized by a target species, and randomly choosing sites within those areas. Monitoring is conducted twice per year, in the spring and fall. In addition, shorebird and visitor censuses are conducted throughout the year.

Thirteen species or taxa were chosen as "key" taxa to serve as a proxy of overall ecological health (Table A). A number of different techniques are used to track the populations of these species.

- Circular Plots

Giant owl limpets (*Lottia gigantea*) are monitored by measuring all individuals greater than 15 mm within a 1-meter diameter circle of a fixed bolt (3.14 $m^{2)}$. This technique yields abundance and size frequency information. There are six circular limpet plots in each zone for a total of 18 plots.

- Line Transects

Line transects were established to target red algal turf (a mixed algal assemblage including erect coralline and fleshy red algal species), surfgrass (*Phyllospadix* spp.), and boa kelp (*Egregia menziesii*). In addition, aggregating anemones (*Anthopleura* spp.) and invasive sargassum weed (*Sargassum muticum*) are always recorded when found, although transects were not designed to specifically target them. There are two of each type of transect in each zone, for a total of 18 transects.

Each transect is marked by three bolts, forming a 10-meter line. A transect tape is laid on the substrate, and the dominant cover is determined along the line in 1-centimeter increments. The resulting data are reported as percent-coverage.

- Photoplots

Rectangular (50 cm x 75 cm) plots were established to target acorn and thatched barnacles (*Chthamalus* spp./*Balanus glandula*, *Tetraclita rubescens*), mussels (*Mytilus* spp.), and rockweed (*Silvetia compressa*, formerly *Pelvetia compressa*). In 1996, plots targeting gooseneck barnacles (*Pollicipes polymerus*) were created by breaking apart line transects that had been used earlier in the program. There are five of the original plot types in each zone; there are six gooseneck barnacle plots in each zone. A total of 63 photoplots are located within the park.

For each plot in each season, a photograph is taken using a 35mm camera with a wide angle lens~~,~~ and a PVC “quadropod” designed to keep the perspective and framing consistent. The resulting slides are projected on a grid of 100 evenly-spaced points, under which the type of cover is determined. The resulting data are reported as percent-coverage.

- Timed Searches

Black abalone (*Haliotis cracherodii*) and ochre seastars (*Pisaster ochraceus*) were rare or absent at the outset of this study, and both are currently still absent from the park. Timed searches are done to document the presence or absence of these two species. A 30 person-minute search is conducted in each zone in appropriate habitat for these animals. In addition, green abalone (*Haliotis fulgens*) were consistently searched for, although they were not an original target species.

- People and Bird Censuses

In addition to biannual monitoring, shorebirds and visitors are monitored throughout the year, ideally on days when tides that are 0.0 feet or lower (mean low low water [MLLW]) fall between 1000 and 1600. The number of actual bird counts has fluctuated greatly in different years due to varying amounts of park staff committed to the endeavor.

An observer begins recording on the cliff above Zone I, and walks the length of all three zones within a half hour before and after the predicted low tide. Within each zone, all people and birds are counted. Birds are identified to species~~,~~ or if not possible, to species category (e.g., terns).

For additional information on CRIMP protocol, refer to *A handbook for monitoring ecological conditions and public use in the intertidal zone of Cabrillo National Monument, San Diego, California* (Engle and Davis 2000a). Presenting more detailed protocols or results of CRIMP are beyond the scope of this document, although a table of summary results is provided in Table B. Results are available in a five-year report (Engle and Davis 2000b) or a ten year report that is in preparation (Becker 2003).

Many of the techniques used in the CHIS program and CRIMP were adopted by other research groups at sites in southern California. In 1997, these groups formally formed the Multi-Agency Rocky Intertidal Network (MARINE) under the administration of Minerals Management Service (Table C). The goal of MARINE is to standardize the methodologies used in these studies to maximize data compatibility. A centralized database including data from over seventy sites allows for a regional perspective that the individual programs cannot provide. All changes made to CRIMP techniques must not compromise its compatibility with these other programs.

C. Goals of CRIMP

At the onset of the ten year review process, it was discovered that there were no codified goals for CRIMP. The following is a prioritized list of goals developed by Bonnie Becker, Marine Biologist, with input from Gary Davis, Jack Engle, Samantha Weber (Cabrillo National Monument [CABR] Chief of

Natural Resource Science), Terry DiMattio (CABR Superintendent), and Karl Pierce (CABR Chief of Interpretation).

- To collect long-term, baseline information on the “ecological health” of the rocky intertidal area, and to determine normal limits of variation.
- To be conducted in perpetuity.
    - *In order to maintain the program in the long-term, all techniques should be doable by volunteers with limited training and basic supervision (by a non-expert) with oversight by a limited number of experienced staff. In addition, the program should be low-cost.*
- To determine differences between the three zones, which experience very different amounts of visitation, and to determine the effects of the closure of Zone III.
- To be comparable and compatible with existing data and similar programs in southern California (e.g. CHIS and MARINE).
    - *Large changes in existing protocols can only be made after consultation with these other programs. Measurements for additional components that are unique to CABR are acceptable.*
- To detect large changes in community structure reasonably quickly.
    - *Correlation of this temporal data with other factors (environmental, anthropogenic) should guide further research to determine causation of trends of concern.*
- To provide for baseline data in case of an acute disturbance (e.g. oil spill, sewage spill, rip rap), and to serve as an opportunity for public education and outreach.

D. Overview of Ten-Year Review Process

In 2000, CABR was awarded a Small Parks ~~s~~ Natural Resources Preservation Program (NRPP) Grant to review the first ten years of CRIMP, 1990-1999. A similar review occurred at CHIS a few months prior. This review had three components: an external statistical review, a workshop of local experts (funded independently by the Cabrillo National Monument Foundation in fiscal year 2001-2002), and a report on suggested changes. Dr. Steven Schroeter, an ecologist from University of California Santa Barbara, was hired to conduct a power analysis of the data. Dr. Schroeter and Richard Smith (Science Explorations) worked on the statistical review from summer 2001 through November 2001. On November 13, 2001, 28 scientists from government, academia and private industry met at the Point Loma Wastewater Treatment Plant to discuss the program and the statistical review (Tables D and E).

A number of goals were designed for this review. Some address the program at large, while others are focused on specific techniques. The goals listed below are those for the general objectives. (See Table F) for complete list of technique-specific questions).

- Does our program meet the goals as we have defined them?
- What is the power of each method to detect changes in targeted population estimates? Do we need more or less samples?
- Specific monitoring design issues: fixed vs. random plots, additional comprehensive surveys, are we characterizing the whole site? How can we improve the program in order to examine potential differences between zones caused by human visitation
- What are the costs and benefits of simplifying or adding additional taxonomic specificity? Are we characterizing rare species?

Participants were asked to list the most important discussion topics for the day. The topics were then prioritized by what was “core” to the program and are listed in Table G. Most of these topics were reviewed in the discussions that followed.

Overview of the power analysis

Steven Schroeter and Richard Smith conducted a power analysis of the data for all techniques except the timed searches. Two different models were used. Before/After comparisons consider the zones separately, and examine the power of the sampling regime to detect hypothetical changes of various magnitudes if they were to occur today (i.e. all of the existing data is considered “before” some sort of impact, with “after” data being modeled at a certain magnitude). Essentially, this model considers the programs ability to detect changes in time (temporal). The second model, Before/After-Control/Impact (BACI) comparisons, compares an area before and after an impact with another area before and after an impact. For example, the model compares the ability to detect an impact in Zone I using Zone III as a "control" site over the same period. All pairwise comparisons of zones were done. This model considers the ability of the program to detect changes between zones over time (spatial and temporal). In both cases, the following were calculated: 1) power to detect 50% changes, 2) percent change detectable with 80% power for a single survey in the After period, and 3) the number of After period surveys required to detect a 50% change with a power of 80%.

A qualitative description of results is given below. A detailed summary of the results is given in Appendix A.

The results for the Before/After model indicated that the power to detect changes within a single zone was high for owl limpet abundances (App. A, Tables 7 – 9), as well as bird and visitor censuses (App. A, Tables 10 – 15). For the photoplots (App. A, Tables 4 – 6) and line transects (App. A, Tables 1 – 3), the power was highest when looking at the target species for a particular set of plots (e.g. mussels in mussel plots). The dominant taxa were generally tracked with high power (e.g. red algal turf in all transects), with some exceptions (especially boa kelp). In addition, the ability to detect changes in bare space was quite high when it was monitored (photoplots, transects). In most cases, the ability to detect changes in rarer taxa was quite low.

In order to conduct the BACI power analysis, the assumptions of additivity and no temporal trends in the differences between zones must be met. Most of the taxa being monitored did not meet those assumptions (App. A, Tables 16, 20). For those that did, the power was highest for the dominant taxa and lower for the rarer taxa. The BACI power was generally lower than the Before/After analysis for line transects (App. A, Tables 17 – 19); the opposite was true for the photoplots (App. A, Tables 21 – 23). None of the comparisons for people counts passed the BACI assumptions. It should be noted that this was not a BACI analysis of the effect of the closure of zone III in 1996, rather an analysis of a hypothetical change that occurs today (i.e. all current data is considered "before" an impact).

At the workshop, Schroeter presented data that indicated that the power of the CRIMP to detect spatial differences was much lower than to detect temporal changes. Gary Davis and Jack Engle noted that the program was not created for spatial comparisons, and that the changes within zones over time was the main focus of the monitoring. Therefore, spatial power analyses are not included in the statistical report. It was also noted that our fixed plots are well designed for detecting long-term ecosytem effects rather than short-term changes. Due to this, short term declines with subsequent increases (recovery) are very hard to detect.

II. Issues and Discussions

A. The General Program

Throughout the discussions, participants stressed the importance of calibrating any changes to the program with the original techniques. This issue is therefore implied in all resulting discussions and should be generally assumed.

- Species inventory

In 1976 and 1978, Dr. Joy Zedler (SDSU) and her team created a comprehensive species list of Cabrillo National Monument (Zedler 1976, Zedler 1978). It was suggested that a systematic survey should be conducted every five or ten years to show changes and note the appearance of range extensions and exotic species.

As part of the NPS Natural Resource Challenge (NRC), the park will be receiving funding to inventory fish species within its boundaries. This survey will begin in FY2002-3. Currently, the NRC does not include funding for non-vertebrates and non-vascular plants. Since 1998, Bonnie Becker, Marine Biologist, has been collecting species information on an ad hoc basis, requesting list information from visiting scientists and knowledgeable workers when possible. In addition, she has noted species when she is certain of best-possible identification. This information, with all other marine species information for the park, has been compiled in an Access database and as of June 2003, it includes over 400 species of plants and animals.

The University of California Santa Cruz "SWAT" Team (Dr. Peter Raimondi, Principal Investigator) has been conducting comprehensive surveys at many MARINE sites. In February 2002, CNMF funded the team to conduct surveys at Cabrillo, which was completed in March 2002. As part of these studies, a species list was generated for Zones I and III of the park. This information has also been added to the database.

In addition, workshop participant Dr. Kaustav Roy received a grant in 2002 to inventory the mollusks of CABR. His inventory is ongoing.

The inventory of the tidepools of Cabrillo National Monument is crucial when using a key species approach to monitoring. It is recommended that funding be directed towards additional "biodiversity-style" sampling—inventories with a specified effort level. These sorts of studies are reproducible and therefore can serve as a tool for tracking change.

- Fixed vs. random plots/tracking patch dynamics

The three main techniques (circular plots, line transects, photoplots) are all based on fixed plots arranged in a stratified random design. This design is beneficial for studies in patchy environments such as the rocky intertidal area, since it allows one to capture variability with a reasonable number of plots (Miller and Ambrose 2000). There are a number of drawbacks, however. The data violate an important assumption of standard parametric statistics since data points are not independent from each other; many statistical tools cannot be used to evaluate trends. It is also not possible to draw conclusions about the entire park, rather only the conditions within the plots can be inferred. In addition, important information about patch dynamics are not being collected with fixed line transects.

This issue has been under consideration since the original monitoring sites were established, and the MARINE Science Committee has discussed it numerous times. The current consensus is to continue existing fixed plot monitoring, but to put the plots into a larger context. This is done through overview photographs from established fixed points. Panoramic digital photos are stitched together and depict a larger-scale view of the site. These photos are of very high resolution and could be used at a future date for unanticipated purposes. It was recommended that overview sites be established at CABR. This was done in Zone I in November 2002, and was completed in the other zones in spring 2003.

The University of California Santa Cruz "SWAT" Team project, mentioned in the species list section above, was designed to address the statistical issues of fixed-plot monitoring at MARINE sites. These surveys are designed to sample random points along a large fixed grid, and include all species encountered (without turning over rocks, using a hand lens, etc.). It was suggested at the workshop that this team should be hired to conduct a survey at CABR. This was completed in March of 2002. Since this work is very time consuming and requires exceptional expertise, it was suggested that they be repeated less frequently, perhaps every three to five years. This work will need to be contracted out.

Other suggestions included directly tracking patches of grass and kelp (analogous to Lagrangian sampling) instead of using fixed plots (analogous to Eulerian sampling) and arranging for semi-regular aerial photographs.

- Costs and benefits of sampling non-target species/taxonomic specificity

The current program includes thirteen "key" species, eleven of which are specifically "targeted" in a circular plot, line transect, photoplot, or timed search. In addition to the two non-targeted key species (anemones and sargassum weed), information on a number of additional species or cover types (such as sand, tar, or bare space) are also collected. The power analysis indicated that the power is extremely low for most species examined except for the specific target of the plot. A few exceptions, such as bare space and in some cases sargassum, were noted.

However, collection of lumped data (such as "red algal turf") reduces the ability to interpret monitoring data ecologically. Given that monitoring occurs over such a large spatial range with high frequencies, range expansions, species invasions, and unusual declines could be well documented by CRIMP and

MARINE. The future is uncertain, and the more data that is collected, the more useful the program could be.

The tension between sampling simplicity and additional taxonomic rigor has been a consistent issue in CRIMP. It is complicated by two additional factors. Firstly, CRIMP is conducted by a mostly volunteer crew; there is a single marine biologist on staff with taxonomic training. The costs of increasing taxonomic specificity are higher at CABR than at most MARINE sites. CRIMP was originally established with a goal of being cheap and relatively easy for a non-expert to do. This allows for more public participation, and ensures the long-term viability of the program in perpetuity.

The second factor is the standardization of MARINE data collecting procedures. These procedures include an expanded “core” species list with optional additional species. This expands the knowledge necessary for the people in the field. In order to remain compatible with this extremely valuable regional collaboration, CRIMP will need to expand its taxonomic specificity.

A number of suggestions were given at the workshop and afterwards to approach this problem. It was suggested that the higher taxonomic resolution might not be appropriately used in standard trend analysis; this data could be collected but not used in many analyses. It was suggested that some of this work should be contracted out by NPS to private or academic vendors. Potentially additional NPS expertise could be hired or shared within the Mediterranean Coast Network (MCN), of which Cabrillo National Monument is one of three parks in addition to Channel Islands National Park and Santa Monica Mountains National Recreation Area. Additional training should be given to more experienced, specialized volunteers. Another suggestion included splitting the sampling period between a number of low tide series, so that the few qualified workers could finish the work with less reliance on volunteers.

This tension persists and is unlikely to be solved without some compromise. Currently, CRIMP has begun to incorporate the MARINE standardization changes. Bonnie Becker has begun to train more experienced volunteers and create “cheat sheets” for them to learn some of the lesser known species. This has been somewhat, although not completely, satisfactory. We will continue to work through this issue.

- Importance of environmental monitoring

Participants stressed the need to collect environmental data while conducting ecological monitoring. Abiotic factors such as temperature, sedimentation, sand depth, water quality, wave action, and tidal elevations were all mentioned.

CABR has been collecting zone-specific temperature information almost continuously since December 1999 and continuously since March 2002 using *in situ* temperature loggers. As part of the Scripps Institution of Oceanography Coastal Data Information Program (CDIP, http://cdip.ucsd.edu), a buoy is located approximately 13.5 kilometers (8.5 miles) offshore of Point Loma. This buoy provides wave direction, energy, and period data from the spring and summer since 1996. In addition, CDIP buoys are located off of La Jolla that measure wind speed and direction as well as air pressure as well as wave statistics. Data is available from these buoys year round starting in 1999. Wave energy and sea bottom temperature has been measured at Scripps Pier for the duration of CRIMP, and wind has been measured since 1995. Scripps Pier is located approximately 25 kilometers from CABR. All of the Scripps data can be used to correlate environmental data with ecological results. In addition, the San Diego Coastal Ocean Observing System (SDCOOS) at Scripps was put online in October 2002; this system collects CODAR surface current data and actual vs. predicted tide height information.

The park has recently (FY 2001-2) purchased a laser-leveler/detector system. We plan to map the tidal heights of all of our fixed plots within the next year or so.

Sand and erosion remain the least-studied abiotic factors within the park. In the fall 2002 and spring 2003 sampling seasons, overview photograph sites have been established. A number of these are located to capture fragile sandstone cliffs and areas where sand tends to fluctuate. These overview photos will provide a qualitative view of large-scale erosion within the park. In addition, Tonya Huff

(Scripps) has begun her doctoral dissertation studies on the effects of sand and human trampling on turf communities. Her studies will provide a more rigorous examination of sand motion within the park and should be an important component of our interpretation of ecological data. Once her work is further along, we should incorporate a sand transport element into the larger program.

- Evaluating the efficacy of the closed area

A major goal of the CRIMP program is to evaluate the effects of the closure of Zone III. When analyzing many of the resulting trends, it becomes clear that some of the data is not appropriate to answer this question. For example, one qualitatively striking effect of high visitation within the park is trampling of red algal turf communities, which leads to dramatic differences in turf height and composition between zone I and zone III. The monitoring of turf percent cover along transects does not pick up this effect. Many of the key taxa are located on the tops of boulders, which do not tend to be as disturbed by human visitation.

The original program was established with a goal of monitoring the “vital signs” of the ecosystem. As a result of this review process, both the power analysis and the workshop, it has become clear that the program is much more effective at detecting temporal changes within a zone (temporal) than differences between zones (spatial). In addition, since zone III was traditionally a low use area, the effects of the closure will be confounded by the original treatment differences.

There were a number of suggestions for dealing with this problem. Measuring turf thickness along the transects would be an easy way to collect information regarding trampling. The participants agreed that evaluation of the efficacy of the closed area was probably not going to be particularly effective or powerful with the current CRIMP program. They suggested that this should be part of a more intense study. Another suggestion was that a rotating closure, either by closing Zone II and opening zone III, or by blocking off parts of zones I and II, would be a worthwhile and valid approach to studying the effects of closure.

Since this workshop, Tonya Huff has begun working on her dissertation research regarding the effects of trampling within the three zones of CABR. Similar studies of the various effects of the closure should be pursued. One possible way to encourage this work is to offer a small grant through CNMF to local students who are interested in studying this question.

- Motile Invertebrates

A number of MARINE groups have begun to enumerate all motile invertebrates within their photoplots. This is not required of all groups, but the possibility of adding them to CRIMP was discussed. It was generally agreed that it would be a large effort for the CRIMP team, since another well-trained person would be needed. One suggestion was to do them every other season, or to do them during an additional low tide period.

It was strongly suggested that at the least, CABR begin to monitor the unicorn snail, *Mexicanthina lugubris*, which appears to be extending its range north from Baja and exerting great predation pressure in the tidepools.

- Power Analysis

There were a number of suggestions on how to extend or modify the existing power analysis. Adding a comparison between power and effort (i.e. benefit and cost) would help to put the power analysis in a more realistic context. Participants suggested that the results of the power analyses of CABR and CHIS were quite different, and it would be a worthwhile endeavor to compare the two.

It was also felt that an alpha value of 0.05, as was used in the power analysis, should have been set at 0.10 due to the inherently noisy nature of ecological data. There was discussion about the need for a serial correlation analysis, although some felt that two samples per year were far enough apart to avoid the problem. Some also felt it would be worthwhile to include considerations of season in the analysis, especially for bird counts and transects. In addition, lumping the transects together, rather than considering the different target species separately, would improve power and is ecologically valid, since the original patches on which the stratification was based have changed over time.

B. Technique-specific discussions

- Circular Plots

There were few discussions regarding the owl limpet plots, and the group generally felt they were worthwhile and well done. Statistical analysis indicates that there is a high power to detect small changes in total density of owl limpets, both temporally (6-9% changes can be detected with 80% power) and spatially (36 to 41% changes could be detected with 80% power). One suggestion included dropping one limpet plot, since the power for six plots was relatively high and removing a plot would decrease the sampling effort needed. However, since many plots are located on unstable cliffs which can completely erode in a single storm, the extra limpet plot can serve as a backup for lost plots.

Plots that have been lost through erosion should be relocated to a nearby, similar spot.

- Line Transects

At the time of the workshop, CRIMP line transects had already changed significantly. In order to standardize with MARINE, we switched from a line intercept to a point intercept method, and changed the sampling interval from 1 centimeter to 10 centimeters. This change did not alter the analysis greatly, but it streamlined the sampling greatly. Since this review included data up to 1999, the new technique was not included in the analysis. It was considered for the workshop, however.

The power to detect temporal changes was highest for surfgrass and turf, and lowest for anemones. The power for boa kelp was lower than the other target species. The power of the technique to detect differences between zones (spatial) was quite low. It was generally agreed that additional line transects should be added due to the low power of the technique and the efficiency of the new technique. However, since the MARINE standardization has taken effect, the speed of sampling has dropped again. One suggestion was to shorten the transects but add more of them; this would increase samples sizes without increasing effort as much.

Boa kelp

CABR is the only MARINE site where boa kelp is targeted. There was some discussion of considering recruitment of this species rather than just percent cover. This was especially true in light of the persistence of surfgrass once it takes over a kelp area. Boa kelp recruits in late April, usually with high levels of recruitment but also high mortality. One suggestion was to include a category for age or stage while determining percent cover. In addition, the fact that how the plant is laying can affect the coverage was of some concern. It was suggested that holdfasts and surfgrass root systems should be counted rather than percent cover. Tagging plants was considered the best approach.

Surfgrass

Most of the discussion about surfgrass was in relationship to boa kelp patches. It was noted that surfgrass can be very well studied using aerial photography.

Red algal turf

The importance of determining the thickness of the turf was agreed upon. One suggested method was using broad thickness categories and a pin that was premarked to use while doing transects. They felt that changes in microinvertebrate communities in different turf types would make an interesting thesis. Since this workshop, Tonya Huff has focused her doctoral research on this question.

The lack of taxonomic specificity was of great concern, since large changes in species composition can follow different types of disturbance. Many of the local experts felt that it would not be possible to identify turf to species. In the recent MARINE standardization, turf has been split into “erect corallines”, *Chondracanthus canaliculatus*, and “other red algae”. This is a compromise for now. At some point in the future, a comprehensive study of turf algal composition should be undertaken at regular intervals.

- Photoplots

The power analysis indicated that power to detect temporal changes was high for target species within a plot, but relatively low for the others. With some exceptions (notably rockweed), power to detect spatial differences was low. In light of the power analysis, it was suggested that we focus more on the species that had reasonable power and stop collecting data on rarer species. This feeds into the tensions described in the "taxonomic resolution" section. Another suggestion was to start monitoring some photoplot species in the transects. This has been done as part of the MARINE standardization. However, very few of the photoplot species are found in habitat where transects are located. Line transects tend to be located on the flat sandstone benches, while photoplots are on the tops of boulders and along the cliffs.

The major issue discussed was whether it would be better to score plots in the field. The advantages include reduced lab time and increased ability to tell apart difficult species. However, this takes more time from an expert participant. MARINE has taken up this issue and has not required groups to either technique. They have, however, switched to digital photographs and electronic scoring (i.e. on the computer). CRIMP has not switched to digital yet, but plans to in the future.

- Timed Searches

There was a lot of concern about timed searches and accounting for density. There was great discussion regarding determining the area searched. It is difficult to quantify due to different tides, irregular topography, and varying amounts effort by observers. Some suggestions included using GPS to mark a specific area, searching a known area and correlating time searched, or just using area and not time. It was also suggested to do more searches but for less time; this would potentially lead to a higher power sampling technique.

Given that this technique is mostly monitoring for absence, the fundamental issue of density is not of immediate importance. It was generally agreed that statistical analysis and power analysis were inappropriate for these data. They serve as powerful evidence of the absence of target species. However, if the populations recover the lack of density measurements could quickly become an important problem. In addition, comparisons with sites that do contain abalone and ochre seastars could become more complicated. Since the workshop, we have been recording approximate area searched during timed searches. A more definitive (yet reasonably simple) solution is still pending. It is likely that we will continue in the same manner, and include in a protocol that if in the future ochre seastars or black abalone are found, efforts to collect density measurements should begin immediately.

- Shorebird & Visitor Censuses

A large amount of time was spent discussing this technique. One problem we tried to solve was the changes in what was considered the border of Zone III. Unfortunately, with changes in staff there has been some variation in this edge. It is of great importance, since the southern ridge of the zone can often contain hundreds of birds, mostly gulls, terns, and pelicans. The differences could be huge, and there is no record of who used which boundary. One suggestion for dealing with this problem while interpreting the data is to remove the major species and reanalyze. Since the workshop, a very clear protocol has been designed to clarify the sampling area during the field surveys.

Park staff was concerned that the current criteria for bird counts was too broad leading to too many sample days, which drains limited staff resources throughout much of the year. Temporal power analysis indicated that the number of samples is more than sufficient. Workshop participants were concerned that the criteria were biasing our results, since we only track birds and visitors at the same time of day, at the same tide level and during the same seasons every year. They suggested that we create a random stratified design in time. For example, we could break the calendar down into the following strata:

- Time of low tide—include early morning and night (although no suggestions were given on how to see birds in the dark)
- Holidays/Weekends/Weekdays
- Height of tide—they suggested we look at higher tides to see how that affects bird behavior

Once each day is assigned a value for these attributes, we could randomly select a smaller number of days, being sure to include an equal number of each category. The number of days could be determined from the power analysis.

In addition, it was suggested that we expand our studies of use to include additional information, such as specific activities and tide level. Birds could be counted separately at different tidal levels. Beach wrack is an important component for shore birds and could be included in a more comprehensive survey.

Currently, we have not made any changes to the criteria we use for counting birds. It will be important to calibrate the new method to the old one. This should be discussed further before a decision is made.

III. Summary of recommendations

Recommendations that have been enacted since the workshop:

- Comprehensive surveys to be conducted every three to four years
- Overview photographs established and taken every season
- Additional taxonomic training for more experienced volunteers
- Study changes in microinvertebrate turf communities
- A clear protocol defining the bird sampling has been developed

Smaller-scale recommendations that should be enacted quickly

- Splitting the sampling between a number of low tides so fewer trained workers can accomplish the work.
- Include a component of turf thickness
- Monitor the unicorn snail *Mexicanthina lugubris*
- Maintain the same number of Lottia plots; relocate those that have broken out
- Consider scoring plots in the field
- Consider using a digital camera for photoplots and scoring them on computer
- Account for area searched for timed searches
- Lower the number of bird sampling days but broaden the criteria used to select them
- All changes should be calibrated to original techniques

Larger-scale studies and recommendations that should be enacted

- A more intense study of effects of closure was highly recommended
- Seek funding towards species inventories with a specified effort level that are repeated at some regular interval
- Aerial photographs to study large patches be taken semi-regularly
- Conduct a study patch dynamics of grass and kelp
- Use of laser-system to map the tidal elevations of all plots
- Focus on coastal erosion and local sediment transport
- Evaluate the costs and benefits of a MARINE-style motile-invertebrate addition to CRIMP
- A more comprehensive survey of turf algal composition at regular intervals
- More comprehensive studies of bird activities

Recommendations to be considered further

- A rotating closure to better determine the effects of closing parts of the rocky intertidal zone
- A small grant through CNMF to local students who are interested in studying this question
- Possibly contracting out more specialized work, or use expertise from other parks
- Extend and modify the current power analyses, including a comparison with the analysis recently completed at Channel Islands National Park results from CHIS would be useful
- Increase the number of transects (possibly shortening them)
- Further studies of boa kelp and surfgrass, consider age and stage, tagging plants
- Change transects from percent cover to holdfasts and root systems

IV. Literature Cited

Becker, Bonnie J. Ten years of rocky intertidal ecological monitoring at Cabrillo National Monument, San Diego, California: 1990-1999. (in preparation). San Diego, CA, National Park Service.

Engle, J.M. and Davis, G.E. (2000a) A handbook for monitoring ecological conditions and public use in the intertidal zone of Cabrillo National Monument, San Diego, California. Sacramento, CA: U.S. Geological Survey.

Engle, J.M. and Davis, G.E. (2000b) Ecological condition and public use of the Cabrillo National Monument intertidal zone 1990-1995. Sacramento, CA: U.S. Geological Survey.

Miller, A.W., and Ambrose, R.F. (2000). Sampling patchy distributions: comparison of sampling designs in rocky intertidal habitats. Marine Ecology Progress Series 196:1-14.

Zedler, Joy B. (1976). Ecological resource inventory of the Cabrillo National Monument intertidal zone: Project 1976 report . United States. National Park Service and San Diego State University. San Diego, CA : San Diego State University.

Zedler, Joy B. (1978). Public use effects in the Cabrillo National Monument intertidal zone: 1978 project report. United States. National Park Service. San Diego, CA, San Diego State University.

Figure 1. Map of study zones (I, II, and III) for the Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP). Zones IA and IIIA are within the administrative boundary of the park, but are not included in the study.

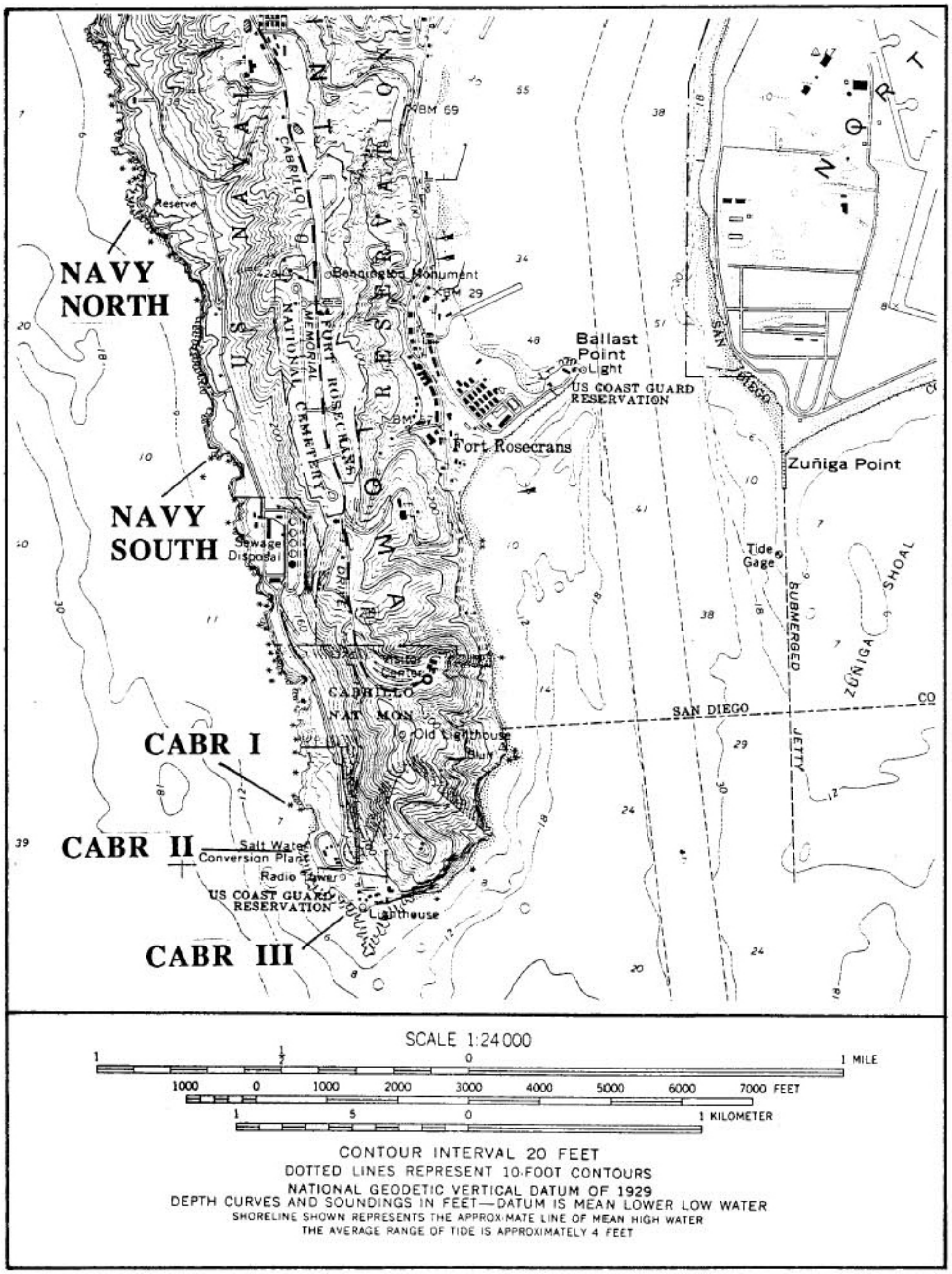

Figure 2. Map of plots and transects in Zone I for the Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP).

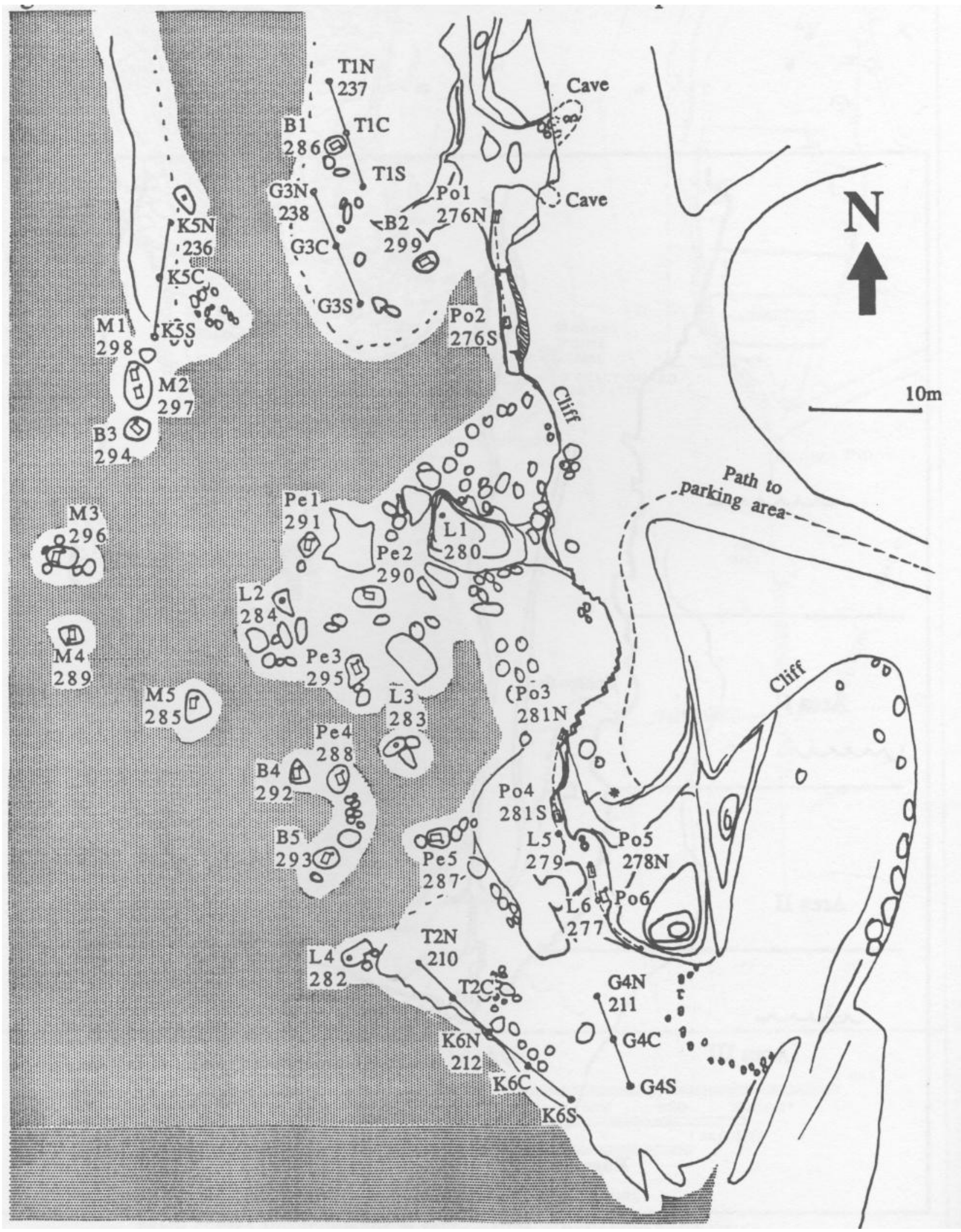

Figure 3. Map of plots and transects in Zone II for the Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP).

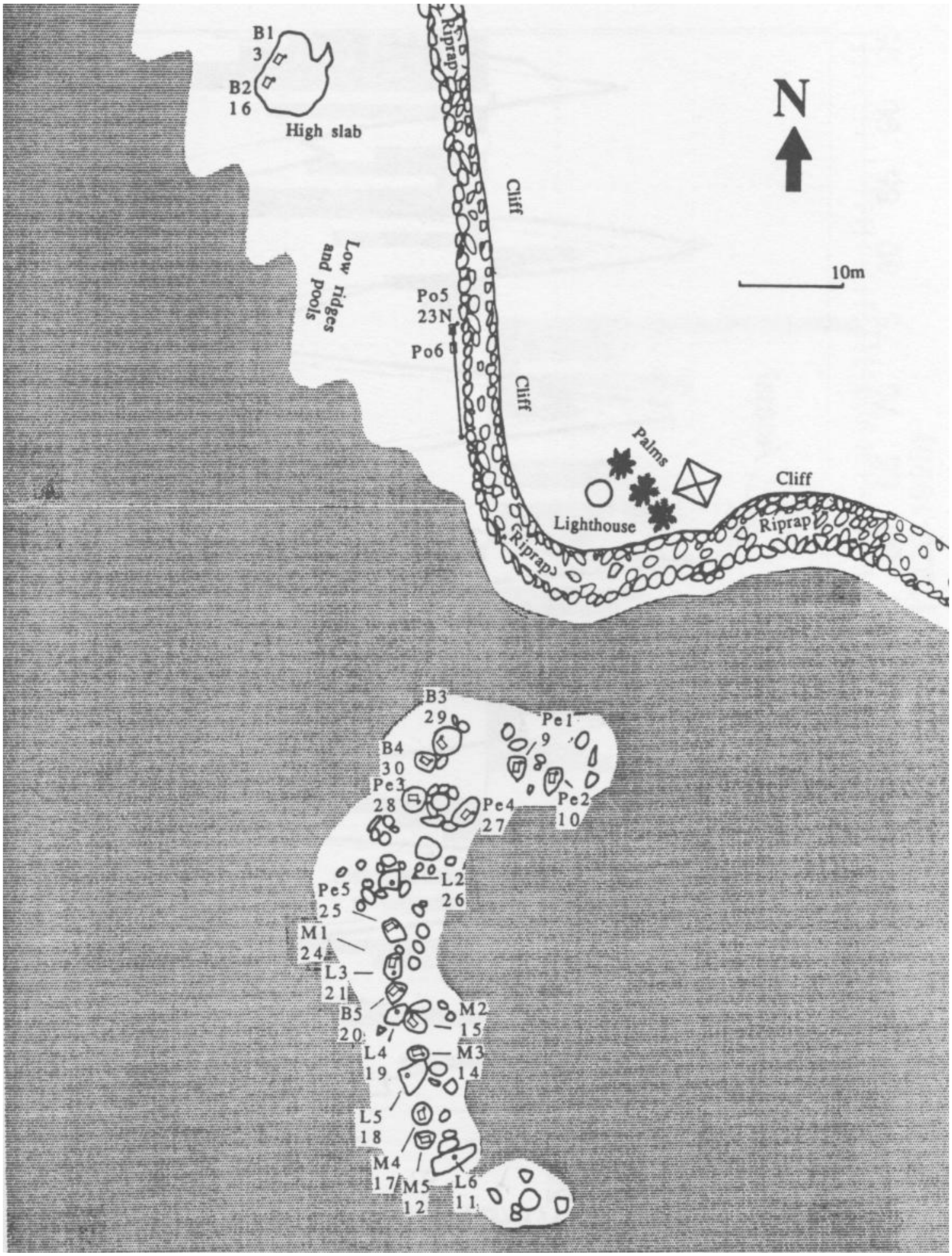

Figure 4. Map of plots and transects in the northern section of Zone III for the Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP).

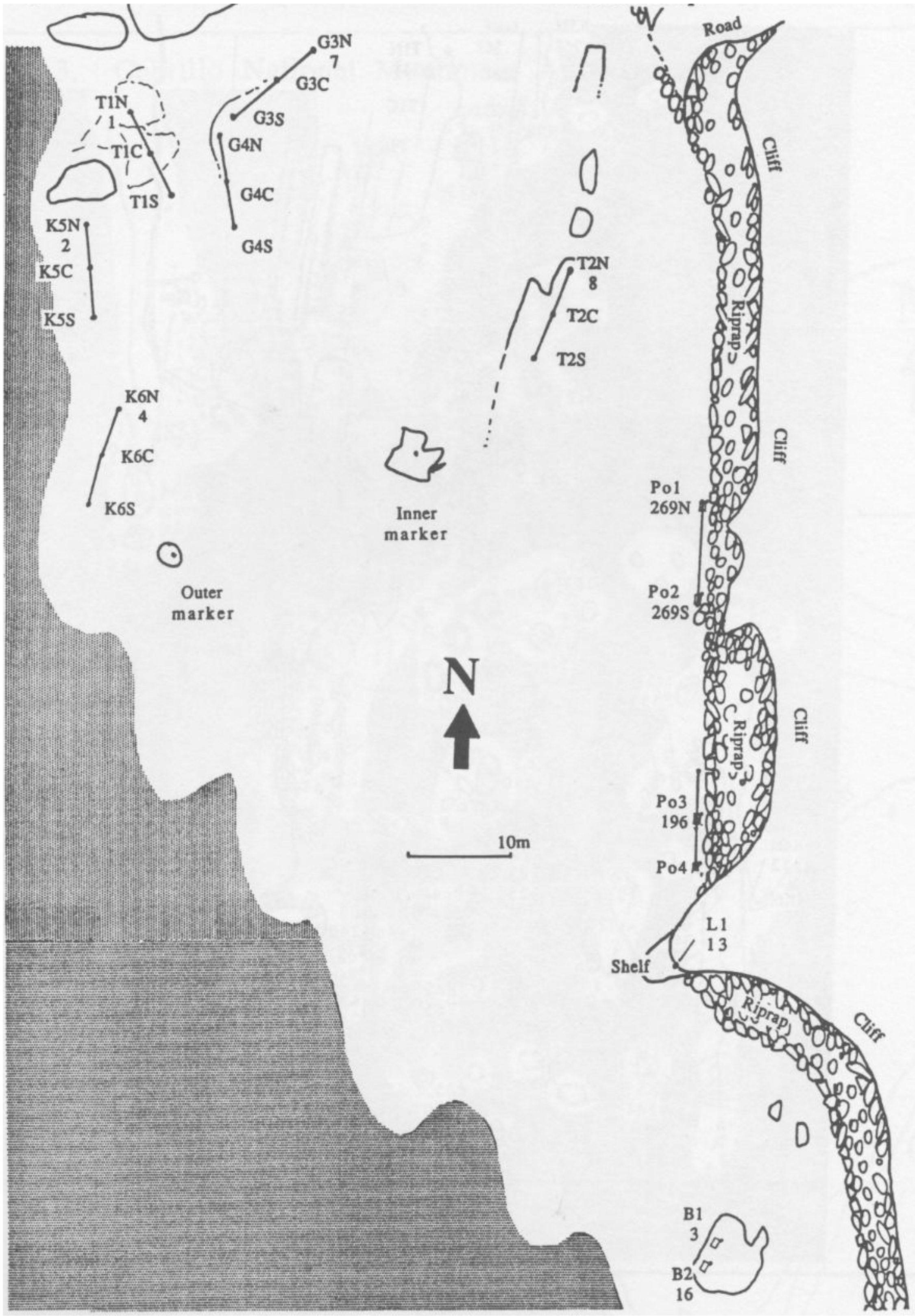

Figure 5. Map of plots and transects in southern section of Zone III for the Cabrillo National Monument Rocky Intertidal Monitoring Program (CRIMP).

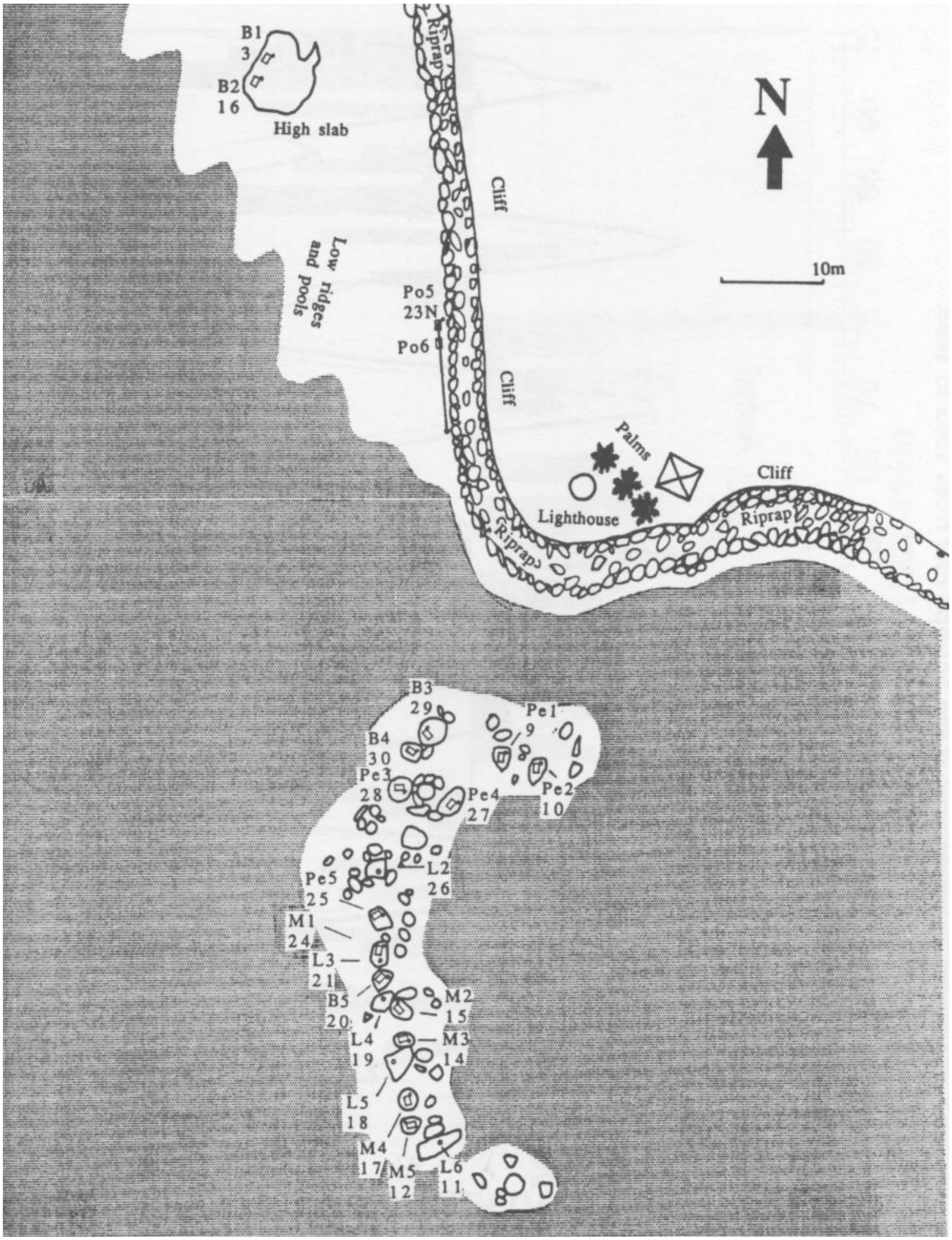

Table A. Key species, monitoring techniques, and the resulting types of data for the Cabrillo National Monument Rocky Intertidal Monitoring Program.

Technique/Taxa	Dimensions of Plot	Number per Zone	Type of Data
Circular Plots:	3.14 m^2	6	Size Frequency
Owl Limpets (*Lottia gigantea*)			
Line Transects:	10 m	6	% Cover
Red Algal Turf (*Corallina* spp. *et. al.*)			
Surf Grass (*Phyllospadix* spp.)			
Boa Kelp (*Egregia menziesii*)			
[Aggregating Anemone (*Anthopleura elegantissima*)]			
[Sargassum Weed (*Sargassum muticum*)]			
Photoplots:	50 x 75 cm	21	% Cover
Acorn Barnacles (*Chthamalus* spp., *Balanus glandula*)			
Thatched Barnacles (*Tetraclita rubescens*)			
Rockweed (*Silvetia compressa*)			
California Mussels (*Mytilus* spp.)			
Goose Barnacles (*Pollicipes polymerus*)			
Timed Search	30 person-minutes	1	Presence/Absence
Black Abalone (*Haliotis cracherodii*)			
[Green Abalone (*Haliotis fulgens*)]*			
Ochre Sea Star (*Pisaster ochraceus*)			

Taxa in brackets are not specifically targeted but are always counted when encountered.

* Not included in the original 13 "key" taxa, but has been consistently counted

Table B. Summary Results of Cabrillo National Monument's Rocky Intertidal Monitoring Program (CRIMP), 1990-1999.

Summary of Results of Univariate Repeated Measures ANOVA

	Time			Zone			Time x Zone			Temporal Trend	Order	Degree
	f	df	p	f	df	p	f	df	p			(Qualitative)
Size Frequency												
Owl Limpets (*Lottia gigantea*)												
Number per Plot	-	-	-	-	-	-	-	-	-	Same	-	-
Average Size	6.84	18	0.000	1.44	2	ns	0.77	36	ns	Decreasing	Linear	Moderate
Percentage <25mm	6.94	18	0.000	3.17	2	ns	1.71	36	ns	Increasing	Linear	Moderate
Average of Largest 10	4.25	18	0.013	1.44	2	ns	1.35	36	ns	Decreasing	Linear	Slight
Line Transects (all transects pooled):												
Red Algal Turf	6.84	18	0.000	0.32	2	ns	1.42	36	ns	Decreasing	Linear	Moderate
Surf Grass (*Phyllospadix spp.*)	8.37	18	0.000	0.06	2	ns	1.26	36	ns	Increasing	Linear	Extreme
Boa Kelp (*Egregia menziesii*)	7.93	18	0.002	0.12	2	ns	0.66	36	ns	Decreasing/ Increasing (?)	Linear/Quadratic	Extreme
Photoplots (plots not pooled):												
Acorn Barnacles (*Chthamalus spp.*, *Balanus glandula*)	10.46	18	0.000	4.02	2	0.046	1.65	36	ns	Increasing	Quadratic	Slight
Thatched Barnacles (*Tetraclita rubescens*)	11.14	18	0.000	0.97	2	ns	0.66	36	ns	Decreasing/ Increasing (?)	Linear/Quadratic	Moderate
Rockweed (*Silvetia compressa*, formerly *Pelvetia fastigiata*)	5.56	18	0.000	3.44	2	ns	1.09	36	ns	Decreasing/Increasing	Quadratic	Slight
California Mussels (*Mytilus* spp.)	11.13	18	0.000	1.41	2	ns	8.66	36	0.000	Decreasing (II, III)/Increasing (I)	3 Linear Trends	Extreme
Goose Barnacles (*Pollicipes polymerus*)	4.40	8	0.010	2.75	2	ns	1.88	16	ns	Increasing	Linear	Moderate

ns=not significant

Table C. List of Multi-Agency Rocky Intertidal Network (MARINE) sites with lead organization (CABR=Cabrillo National Monument, National Park Service, CHIS=Channel Islands National Park, National Park Service, CSU Fullerton=California State University Fullerton, UCLA=University of California Los Angeles, UCSB=University of California Santa Barbara, UCSC=University of California Santa Cruz)

MAINLAND SITES	Organization*
San Luis Obispo County	
Pt. Sierra Nevada	UCSC
Cayucos	UCSC
Hazard's	UCSC
Piedra Blancas	UCSC
Rancho Marino	UCSC
Shell Beach	UCSC
Santa Barbara County	
Occulto	UCSC
Alegria	UCLA
Arroyo Hondo	UCLA
Boathouse	UCSC
Carpinteria	UCLA
Coal Oil Pt.	UCLA
Government Point	UCSC
Purisima	UCSC
Stairs	UCSC
Ventura County	
Mussel Shoals	UCLA
Old Stairs	UCLA
Los Angeles County	
Paradise Cove	UCLA
Point Fermin	UCLA
White's Point	UCLA
Orange County	
Crystal Cove	CSU Fullerton
Dana Point	CSU Fullerton
Shaws Cove	CSU Fullerton
Treasure Island	CSU Fullerton
San Diego County	
Cardiff Reef	UCSB
Cabrillo I	CABR
Cabrillo II	CABR
Cabrillo III	CABR
Navy North	UCSB
Navy South	UCSB

ISLANDS SITES	Organization*
San Miguel Island	
Otter Harbor	CHIS
Crook Point	CHIS
Cuyler Harbor	CHIS
Harris Point	CHIS
Santa Rosa Island	
NW Talcott	CHIS
East Pt.	CHIS
Ford Pt.	CHIS
Fossil Reef	CHIS
Johnson'sLee	CHIS
Santa Cruz Island	
Fraser	CHIS
Orizaba	CHIS
Prisoner's	CHIS
Scorpion	CHIS
Trailer	CHIS
Willows	CHIS
Anacapa Island	
E/W Middle	CHIS
Cat Rock	CHIS
Frenchy's Cove	CHIS
Harbor Seal	CHIS
Santa Barbara Island	
Landing Cove	CHIS
Sea Lion Rookery	CHIS
Santa Catalina Island	
Bird Rock	CHIS
Little Harbor	CHIS

Table D. Participants in the Cabrillo National Monument Rocky Intertidal Monitoring Program Ten Year Performance Review Workshop, Point Loma Wastewater Treatment Facility, November 13, 2001.

Name	Institution
Rich Ambrose	University of California Los Angeles
Bonnie Becker	Cabrillo National Monument (National Park Service)/Scripps Institution of Oceanography
Laura Ball	City of San Diego
Rebecca Clark	Cabrillo National Monument (National Park Service)
Tish Conway-Cranos	University of California Santa Cruz/Mineral Management Service
Allen Collins	University of California San Diego
Eric Cox	California State University Fullerton
Terry DiMattio	Cabrillo National Monument (National Park Service)
Mary Elaine Dunaway	Mineral Management Service
Gary Davis	Channel Islands National Park (National Park Service)
Matthew Edwards	University of California Santa Cruz/San Diego State University
Jack Engle	University of California Santa Barbara
Liliana Fajardo	Cabrillo National Monument (National Park Service, volunteer)
Steven Fradkin	Olympic National Park (National Park Service)
Susan Frisch	California State University Fullerton
Mike Graham	University of California Davis
Sarah Henkel	California State University Fullerton
Chris Janousek	Scripps Institution of Oceanography
Maurice Hill	Mineral Management Service
Tonya Huff	Scripps Institution of Oceanography
Megan Johnson	Merkel Associates
Carol Knipper	Cabrillo National Monument (National Park Service)
Tiffany Luas	California State University Fullerton
Steve Murray	California State University Fullerton
Christy Roe	University of California Santa Cruz
Kristin Riser	Scripps Institution of Oceanography
Kautav Roy	University of California San Diego
Lynnette Vesco	Mineral Management Service
Nacho Vilchis	Scripps Institution of Oceanography
Samantha Weber	Cabrillo National Monument (National Park Service)
Melissa Wilson	University of California Santa Cruz

Table E. Agenda of the Cabrillo National Monument Rocky Intertidal Monitoring Program Ten Year Performance Review Workshop, Point Loma Wastewater Treatment Facility, November 13, 2001.

0830	Assemble, light refreshments
0900	Welcoming remarks by Samantha Weber, Chief of Natural Resource Science, Cabrillo National Monument (CABR)
0915	Introduction to CABR Rocky Intertidal Monitoring Program by Bonnie Becker, Marine Biologist, CABR
1030	Results of review by Steve Schroeter, University of California Santa Barbara
1230	Lunch break
1315	Group discussion—general program individual techniques
1430	Break for field trip
1500	Field trip to tidepools
1615	Conclude

Table F. Goals of Cabrillo National Monument Rocky Intertidal Monitoring Program Ten Year Performance Review.

General questions:

- Does our program meet the goals as we have defined them?
- What is the power of each method to detect changes in targeted population estimates? Do we need more or less samples?
- Specific monitoring design issues: fixed vs. random plots, additional comprehensive surveys, are we characterizing the whole site? How can we improve the program in order to examine potential differences between zones caused by human visitation
- What are the costs and benefits of simplifying or adding additional taxonomic specificity? Are we characterizing rare species?

Photoplots

- What level of specificity should we score the slides?
- Scoring in the field? Is it possible with our current resources? Calibration?
- How much variability is there in slides scored by different people?
- Is it possible to add a size frequency component for any of the species?

Circular Plots

- Can we correlate the patterns we see with any environmental variables?

Line transects

- We have recently changed our protocol, should we add some additional plots?
- What level of taxonomic specificity should we be using?
- Should we include an index of trampling pressure? Turf thickness, turf composition?
- How well is this method monitoring rarer species that it is supposed to be “targeting”, such as anemones and more importantly, Sargassum?

Timed searches

- Is this data useful?
- Should we try to standardize this technique more?

Bird counts/human censuses

- Can we get useful information from this data given the past problems in standardizing the technique?
- Are there benefits to conducting so many surveys, or would fewer suffice?

Table G. Discussion list as determined by participants of the Cabrillo National Monument Rocky Intertidal Monitoring Program Ten Year Performance Review Workshop, Point Loma Wastewater Treatment Facility, November 13, 2001.

List of Topics to discuss (numbered are the core topics, bulleted not core)

1. Create baseline species inventory/survey – alien spp.
2. Patch dynamics- assess size & location
3. Improve efficiency of bird/visitor sampling
4. Improve power of photo/transect for target spp. (BACI)
    a. Compare performance evaluation of CHIS & CABR
5. Add standard overview photo (MARINE protocol)
6. Increase taxonomic resolution
7. Refine or replace timed searches
8. Goals of program
9. Spatial vs. temporal power

- Target study of trampling on algal turf
- Evaluate closed area (more $FTE)
- Evaluate cost of sampling non-target spp.
- Target study of mussel crash
- Additional environmental monitoring
- Add settlement dynamics
- More strategic studies
- ID & market strategic needs (resource management plan)
- Consider establishing a science review panel
- Participate in Regional MARINE (provide context for monitoring with other monitoring regionally)
- Reserve effects

Statistical evaluation of the long-term monitoring program of the Cabrillo National Monument

Stephen Schroeter[1]

and

Richard. O. Smith[2]

[1] Research Ecologist, Marine Science Institute, University of California, Santa Barbara, California 93106

[2] Science Explorations, 2270 Camino Vida Roble, Suite L, Carlsbad, California 92009

Executive Summary

The monitoring program at the Cabrillo National Monument from 1990 through 2001 was evaluated by performing power analyses on data collected in five types of sampling: 1) line transects, 2) photo plots, 3) Owl limpet counts, 4) Bird counts, and 5) People counts. All samples were conducted in fixed areas of various sizes semi-annually in each of three zones that into which the monument is divided. Line transects and photo plots estimated abundance as the planar percent cover of total habitat, while owl limpet, bird, and people counts estimated abundance as number per unit area. Line transect and photo plots were established in habitats dominated by particular taxa. For example, line transects were established in habitats dominated by Surfgrass (*Phyllospadix spadicea*), Boa Kelp (*Egregia menziesii*), and red algal turf while photo plots were established in habitats dominated by Acorn Barnacles (*Balanus* spp., *Chthamalus* spp., and *Tetraclita rubescens*), Gooseneck barnacles (*Pollicipes polymerus*), Mussels (*Mytilus* spp.), and Rockweed (*Pelvetia fastigiata*). Power analyses were conducted on two kinds of statistical models: Before/After comparisons and Before/After – Control/Impact or BACI comparisons, using all data through 2001. Each power analysis had the following components: 1) power to detect 50% changes, 2) Percent change detectable with 80% power for a single survey in the After period, and 3) The number of After period surveys required to detect a 50% change with a power of 80%. Before/After analyses estimated power or survey numbers for changes from Before to After periods for a single zone, whereas analyses based on the BACI model estimated power for Before to After changes in differences between two zones.

The power to detect Before vs. After changes for a single zone was generally high for Owl Limpet, Bird, and People counts. Power was also high for taxa sampled with line transects and photo plots for dominant species in a particular habitat type. By contrast, power to detect changes for non-dominants was generally low. Power to detect changes in bare space and thus total biological cover, was generally high for both line transects and photo plots.

High proportions of the taxa for the five monitoring protocols failed to pass the assumptions of additivity or no temporal trends in the differences between pairs of zones - line transects: 70%, photo plots: 96%, owl limpet plots: 67%, bird counts: 83%, and people counts: 100%. As with Before/After comparisons, the power to detect changes for BACI comparisons for line transects was generally higher for dominant taxa in a particular habitat. However, the power to detect changes was generally much lower for BACI than Before/After comparisons. By contrast, the power for BACI comparisons for photo plots was generally very high. Power to detect changes for the single BACI comparison of owl limpets that passed the assumptions tests ranged from 6% to 81%. Power to detect changes was low for non-marine birds and high for shore birds. None of the comparisons for people counts passed the BACI assumptions.

1.1 Introduction

Long-term monitoring of biological resources and public use in rocky intertidal habitats at Cabrillo National Monument (CNM) began in 1990. One goal of this monitoring is to assess an ever-growing impact of human activity on the rocky intertidal biota. Another is to gather data which might be useful in evaluating any number of possible natural (e.g. large storms) or anthropogenic (e.g. oil or sewage spills) on the rocky intertidal community at Cabrillo National Monument. Monitoring at CNM comprises different tasks centered around the following habitats or biota: 1) Percent cover estimates on transects, 2) Percent cover estimates in photographic plots, 3) Density and population size distribution estimates of the giant owl limpet, *Lottia gigantea*, in circular plots, 4) Density estimates of birds, and finally, 5) Indices of human use based on density estimates of the number of visitors per day. All six measurements are made in fixed sampling replicates in each of three Zones into which the Monument was divided. From north to south these are designated Zones I, II, and III (Fig. 1 of Workshop Summary Report). Based on the location of public access points, these areas follow a gradient in human use, with zone I being the presumed highest and III the lowest. In addition to these studies, rare species (e.g. abalones and sea stars) were monitored to detect possible increases in the future. Power analyses were not performed on these data.

1. 2. Goals.

The goal of this review is to evaluate the adequacy of the monitoring design by performing power analyses. These power analyses are based on two statistical models commonly used to assess the effects of a perturbation. One is the “Before/After” model which compares abundances of a given taxon at a particular location (e.g. Zones I, II, or III) Before and After the date on which a perturbation has occurred. This analysis is also referred to as intervention analysis (IA). Its rationale is to compare a time series at a given location Before and After a perturbation of interest (Stewart-Oaten and Bence, 2001). Box and Tiao (1975) provide an example in which IA was used to assess the effects of pollution controls on air quality variables in the Los Angeles Basin. The other approach is the Before/After-Control/Impact or BACI design (Stewart-Oaten and Bence, 2001) which compares the means of the differences between an Impact and un-impacted Control site between time periods Before and After a perturbation has occurred. Definitions of Before and After periods could also be tailored to assess historical changes in abundance (e.g. Before and After the first decade of monitoring). The BACI design differs from the Before/After by using data from one or more control sites as a covariate. Under certain conditions, the BACI design can provide stronger inferences about effects of a putative impact by separating out possible site-specific effects from those of a perturbation. The BACI model requires that the “deltas” (the differences or ratios between abundances at the Impact and Control sites, referred to as I-C) must be independent, additive, and display no trends over time. Schroeter et al. (1993) used BACI analyses to assess the possible impacts of the cooling water discharge of an open coast nuclear power plant on a nearby kelp forest. Both the BA and BACI analyses are predicated on detecting impacts of un-replicated designs in which an impact occurs at a particular place at a particular time, and both apply to the monitoring program at the Cabrillo National Monument at which there are three Zones along the shore each vulnerable to potential human or natural impacts. In the event of an impact to one or more Zones (e.g. sewage or oil spill), both BA and BACI analyses could be applied to determine the effects and significance of such impacts.

The aims of the power analyses for both the Before/After and BACI models are: 1) to calculate the power of detecting specified differences (e.g. ± 50%); 2) to specify the size of a difference necessary to achieve power of 80% for a constant sample size; and 3) to specify the sample size necessary for power of 80% and a specified difference (e.g. ± 50%).

Both Before/After and BACI power analyses were done by assuming that all monitoring data collected through 2000 belonged the period Before any large human or natural disturbance.

2.0 Before/After Comparisons

2.1. Methods

Line Transects. Fixed transects were located in three types of habitats in each of the three Zones at the beginning of the monitoring program. These habitats corresponded to the dominant biota at the time and are designated: Boa Kelp, Surf Grass, and Red Algal Turf. There were 2 replicate 10-meter long line transects sampled within each zone and habitat types on each of 21 semi-annual surveys conducted from 1990 through 2000. Analyses were done to detect the power of detecting a 50% change from the Before period to a single After survey; the change in abundance from the Before period to a single After survey required for a power of 80%, and finally, the number of After surveys required to detect a 50% change in abundance from the Before to After periods with a power of 80%. All power analyses used a significance level (α) of 0.05

Photo Plots. Fixed photographic plots were located in four types of habitats in each of the three Zones at the beginning of the monitoring program. These habitats corresponded to the dominant biota at the time and are designated: Acorn Barnacles, Gooseneck Barnacles, Rockweed, and Mussels. There were 5 or 6 replicate photo plots sampled within each zone and plot type on each of 20 semi-annual surveys conducted from 1990 through 2000. Analyses were done to detect the power of detecting a 50% change from the Before period to a single After survey; the change in abundance from the Before period to a single After survey required for a power of 80%, and finally, the number of After surveys required to detect a 50% change in abundance from the Before to After periods with a power of 80%. All power analyses used a significance level (α) of 0.05.

Lottia Plots. *Lottia gigantea* (giant owl limpet) were counted and measured in 6 replicate circular plots 1 meter in radius within each zone on semi-annual surveys from 1990 to 2000. The data were converted to number per acre and log-transformed (log(x+1)) prior to power analyses.

Bird Counts. The number of birds were recorded on two taxonomic levels, species and species categories, as part of routine patrols of the shore during low tides. The four species categories were: Sea Birds, Shore Birds, Wading Birds, and Other. The last category includes mainly terrestrial or transient species (e.g. Black Phoebes). Analyses were performed on the 4 species categories. Counts in categories were converted to number per acre and log-transformed prior to power analyses.

Human use. The number of people in each zone were recorded as part of routine patrols of the shore during low tides. Counts in categories were converted to number per acre and log-transformed prior to power analyses.

2.2 Results

Line Transects. Power to detect 50% changes in abundance in Before vs. After comparisons were generally high for the dominant taxa within each plot type, but were generally very low for non-dominant taxa (e.g. *Anthopleura*, Table 1). Power was high for the category “Bare Substrate”. This is a useful result, because (100% -(Percent Cover of Bare Substrate)) is a measure of total biological cover.

The magnitude of changes in abundance detectable with 80% power are near or less than 50% for dominant taxa in each plot type. For non-dominant taxa, the sampling design is generally unable to detect 99% changes with any power (Table 2).

Less than 10 "After" surveys are required to detect 50% changes in the abundance of dominant taxa within each plot type. By contrast, for most non-dominant taxa, 10 years of semi-annual surveys would not be sufficient to detect a 50% change from Before to After with 80% power (Table 3).

Results for one non-dominant taxon, the non-native Sargassum weed (*Sargassum muticum)* show that for some zones there is reasonably good power to detect changes of 50% or smaller (Tables 1-3).

Photo plots. Power to detect 50% changes in abundance in Before vs. After comparisons were generally high for the dominant taxa within each plot type, but generally very low for non-dominant taxa (e.g. *Anthopleura* and coralline crusts, Table 4). As was the case for line transect estimates, power was high for the category "Bare Substrate". This is a useful measure because (100%-Percent Cover of Bare Substrate)) is a measure of total biological cover.

The magnitude of changes in abundance detectable with 80% power are near or less than 50% for dominant taxa in each plot type. For non-dominant taxa, the sampling design is generally unable to detect 99% changes with any power (Table 5).

Less than 10 "After" surveys are required to detect 50% changes in the abundance of dominant taxa within each plot type. By contrast, for most non-dominant taxa, 10 years of semi-annual surveys would not be sufficient to detect a 50% change from Before to After with 80% power (Table 6).

Results for one non-dominant taxon, the non-native Sargassum weed (*Sargassum muticum)* show that for some zones, there is reasonably good power to detect changes of 50% or smaller (Tables 1-3).

Lottia Plots. Power to detect 50% changes in total abundance of Lottia was high for all zones (Table 7). Changes of 6% to 9% in total Lottia abundance from Before to After were detectable with power of 80% (Table 8). A single survey in the After period was sufficient to detect 50% differences from Before to After in all zones (Table 9).

Bird Censuses. The power to detect 50% changes in abundance of all bird species categories other than Other species in Before vs. After comparisons was high (Table 10). The sampling program is able to detect small Before/After differences (15% to 24% changes; Table 11). Excluding Other, 50% changes in abundance from Before to After were detectable with a single After survey (Table 12).

Human Uses. The power to detect 50% changes in number of people in a zone in Before vs. After comparisons was high (Table 13). The sampling program is able to detect small Before/After differences (7% to 36% changes; Table 14). Fifty percent changes in abundance from Before to After were detectable with a single After survey (Table 15).

3.0 BACI Comparisons

3.1 Methods

Data used for power calculations for BACI comparisons were identical to those used for the power analyses of Before/After comparisons. Abundance estimates (% cover or density) were transformed [arcsin(sqrt(percent cover/100)) or log10(density+1)), and the mean abundance of each taxon in each habitat and zone was calculated for each survey. The means were used to calculate differences between Zones, termed "deltas" for each taxon and habitat type on each survey. Prior to conducting power analyses, the deltas were subjected to tests of additivity and linear trends over time. Data passing these assumption tests were then used in power analyses in which all surveys were considered to be in the "Before" period. As with the Before/After comparisons, analyses were done to determine the power of detecting a 50% change in the deltas from Before to After for each of three comparisons (Zone I vs. Zone II, Zone I vs. Zone III, and Zone II vs. Zone III); the change in deltas from the Before period to a single After survey required for a power of 80%, and finally, and the number of After surveys required to detect a 50% change in deltas from the Before to After periods with a power of 80%. A significance level (α) of 0.05 was used in all analyses.

3.2. Results

Line Transects. Of the 60 possible comparisons between Zones for the taxa sampled with line transects, 18 passed both the assumptions of additivity and no temporal trends (Table 16). Power to detect 50% changes in abundance were generally very low (Table 17). For most taxa, it was not possible to detect total extinction or total dominance in one Zone relative to another with power of 80% for a single "After" survey (Table 18). Only four of the taxon by Zone comparisons had power of 80% with the number of surveys in the After period less than or equal to the number of surveys in the Before period (Table 19).

Photo plots. Of 105 possible Zones by Taxon comparisons, 9 passed both the assumptions of additivity and no temporal trends (Table 20). By contrast to the comparisons for transect data, power to detect 50% changes in abundance were generally high for taxa and plot types passing the assumption tests (Table 21). With two exceptions, it was possible to detect changes in deltas of 50% or less (Table 22) and for most taxa, it was possible to detect 50% changes in abundance of a taxon in a given habitat from one Zone relative to another with power of 80% for a single "After" survey (Table 23).

Owl limpet (*Lottia gigantea) Plots*. One of the three between Zone comparisons passed the assumptions of both additivity and no temporal trends for deltas of total Lottia density. (Zone I vs. Zone III; Table 24). The power to detect changes in deltas from Before to After was low (Tables 24 & 25), even when the number of samples in the After period equaled the number in the Before period (Table 26).

Bird Counts. Two of the twelve possible comparisons between Zone by Taxon comparisons passed the assumptions of both additivity and no temporal trends ((Zone I vs. Zone II, Other species and Shore Birds; Table 27). The power to detect changes in deltas from Before to After was high for shore birds and low for other species (Tables 28 & 29). Power to detect change was low for Other Bird species even when the number of samples in the After period equaled the number in the Before period (Table 29). By contrast, for Shore Birds, the power to detect a 50% change in deltas from the Before to After period was high with only a single After period survey (Table 29).

People Counts. One of the three between-Zone comparisons passed the assumptions of both additivity and no temporal trends for deltas of human censuses (Table 30), rendering these data unsuitable for BACI comparisons.

4. Summary

4.1 Before/After Comparisons

Power for taxa sampled in line transects was sufficient for Surf Grass and Boa Kelp in plots where they dominate and generally high for Red Algal Turf in all three plot types (Surf Grass, Boa Kelp, and Red Algal turf). Power to detect Before/After changes in the percent cover of Bare Space is also generally high. This is useful, since it means that the power to detect Before/After changes of total biological cover (100% - Percent Cover of Bare Space) is also high.

The pattern of power in Photo Plots was generally similar to that for Line Transects: high power to detect Before/After changes for dominants in a particular plot type, low power for non-dominants. The power to detect Before/After changes in biota sampled in Photo Plots was low for most of the taxa sampled in Photo Plots, however, power was high for Bare Substrate, Acorn Barnacles (*Balanus* + *Chthamalus*) in Acorn Barnacle and Rockweed in Acorn Barnacle plots; Acorn Barnacles, Gooseneck Barnacle, and Bare Space in Gooseneck Barnacle plots; Bare Substrate, Other Plants and Other Animals in Mussel plots; and Bare Substrate and Rockweed (*Pelvetia*) in Rockweed plots.

Power was generally high to detect small changes in Before/After comparisons of total numbers of Owl Limpets, all categories of Birds except Other species, and People densities.

4.2 BACI Comparisons. Relatively few of the taxa and zone-to-zone comparisons passed the statistical screens required for BACI analyses. Of those that passed, power was generally low for Line Transects and Owl Limpets and generally high for taxa from Photo plots and Bird censuses. None of the zone-to-zone comparisons for human use passed the assumption screens for BACI analyses.

5.0 Conclusions

Although BACI analyses allow for strong inferences about the likely causes of changes in abundances following a man-made or natural perturbation, the data from the CNM monitoring program generally did not fulfill the underlying assumptions. Power to detect changes for BACI comparisons was generally high for photo plot data, generally low for line transect data, and mixed for owl limpet and bird counts. Data for people counts did not pass either the additivity and no trends assumptions. A possible reason for this is that abundances of many of the biological variables (including people) differed greatly among the different zones, which tends to result in multiplicative rather than additive differences among zones. For example, consider a case in which abundance at a Control site averages 0.1 m^{-2} and 1 m^{-2} at an Impact site in the Before period. Further assume that abundances at both sites are reduced by 50% in the After period by a large-scale environmental change such as an El Nino. The delta in the Before would be 0.9 m^{-2} and 0.45 m^{-2} in the After period, leading one to conclude erroneously that there was a relative decline of 50% at the Impact site from Before to After. Log transformation should scale the data so that such an illusory impact won't be detected, however, such a transformation is generally not appropriate for percent cover data (collected on line transects and photo plots), so the problem remains. Disparate densities between locations coupled with large-scale changes in mean abundances can also lead in some cases to linear trends in between-site differences.

Changes in distribution along the tidal gradient combined with fixed line transects that were generally laid along a single elevation may also have lead to an exaggeration of differences in abundance among zones and thus a failure of abundances between zones to "track" over time. A possible remedy to this problem would be to add transects perpendicular to the tidal gradient in the middle of each line transect. Percent cover estimates could be made on these transects as well, or they could simply be used to record the dimensions of selected taxa (e.g. Surfgrass) across the tidal gradient. The problem with this is that it involves "starting from scratch" and wouldn't be able to take advantage of the relatively long time series of the monitoring program. Another possible remedy, particularly for line transects, would be to use long-term aerial photographic data to collect data on the area occupied by a particular species and its position up and down the shore. Surf grass (*Phyllospadix spadicea*) may be particularly amenable to this approach, since patches can be easily delineated from aerial photographs. Red algal turf may be another promising candidate. One possible way to increase the number of taxa amenable to BACI analyses would be to censor the data by matching up sampling replicates with similar values of species of interest in the first year. This could help to increase the power to detect changes.

Even though the range of possible taxa and comparisons and power was generally low for the BACI comparisons, several of the taxa were amenable and will be useful in assessing possible future impacts. This combined with the fact that power was generally high for Before/After comparisons for many more taxa (e.g. total abundance of owl limpets, bird and people counts, and most dominant species in the habitat types targeted by line transects and photo plots) indicates that the monitoring protocols for the Cabrillo National Monument will be useful in assessing possible environmental impacts in the future.

7.0 Tables

Table 1. Power to detect 50% changes in percent cover of taxa sampled in line transects in Before vs. After comparisons. Significance level (alpha) = 0.05

		Back transformed Mean % cover by Zone			Power to detect 50% change by Zone			Averages Among Zones	
Plot Type	Taxon	I	II	III	I	II	III	Mean	std
Surfgrass	Aggregating Anemone	0.0	0.0	0.0			6.4	6.4	
Surfgrass	Bare Substrate	2.4	2.3	6.2	88.8	56.1	95.5	80.1	21.1
Surfgrass	Boa Kelp	0.5	2.4	0.6	24.3	51.1	41.4	38.9	13.6
Surfgrass	Other Biota	0.2	1.6	0.3	25.7	64.6	22.9	37.7	23.3
Surfgrass	Red Algal Turf	14.0	8.2	15.8	99.9	99.8	100	99.9	0.1
Surfgrass	Sargassum Weed	0.0	0.7	4.1	15.8	37.5	72.5	41.9	28.6
Surfgrass	Surf Grass	79.1	78.1	66.5	100	100	100	100.0	0.0
Boa Kelp	Aggregating Anemone	0.0	0.0	0.0	6.4	9.3	9.5	8.4	1.7
Boa Kelp	Bare Substrate	2.2	1.2	4.8	77.4	55.2	84.5	72.4	15.3
Boa Kelp	Boa Kelp	11.5	8.5	8.1	68.9	60.6	64.2	64.6	4.2
Boa Kelp	Other Biota	4.1	1.1	8.1	53.9	42	98.7	64.9	29.9
Boa Kelp	Red Algal Turf	23.3	15.4	41.3	100	97.1	100	99.0	1.7
Boa Kelp	Sargassum Weed	0.1	0.0	2.4	10.7	9.6	65.2	28.5	31.8
Boa Kelp	Surf Grass	42.5	62.4	20.5	100	100	99.5	99.8	0.3
Red Algal Turf	Aggregating Anemone	0.5	0.4	0.9	73.1	50	97.5	73.5	23.8
Red Algal Turf	Bare Substrate	0.6	7.8	4.4	66.5	97.4	84.9	82.9	15.5
Red Algal Turf	Boa Kelp	0.2	0.4	0.0	17.6	26.3		22.0	6.2
Red Algal Turf	Other Biota	0.1	0.2	0.2	23.2	23.2	21.8	22.7	0.8
Red Algal Turf	Red Algal Turf	84.4	72.3	88.5	100	100	100	100.0	0.0
Red Algal Turf	Sargassum Weed	0.0	0.1	0.0	7.9	18.7	9.4	12.0	5.9
Red Algal Turf	Surf Grass	8.8	12.3	2.1	59.6	93.5	52.5	68.5	21.9

Table 2. Percent changes in Before vs. After comparisons detectable with power of 80% and significance level of 5%.

		Back-transformed mean % cover by Zone			Zone					
					I		II		III	
Plot Type	Taxon	I	II	III	%Δ	power	%Δ	power	Δ	power
Surfgrass	Aggregating Anemone	0.0	0.0	0	99		99		99	10.6
Surfgrass	Bare Substrate	2.4	2.3	6.2	50	88.8	67	80.8	50	95.5
Surfgrass	Boa Kelp	0.5	2.4	0.6	99	70.5	71	80.5	81	80.5
Surfgrass	Other Biota	0.2	1.6	0.3	99	73.5	61	81.3	99	67.3
Surfgrass	Red Algal Turf	14.0	8.2	15.8	50	99.9	50	99.8	50	100.0
Surfgrass	Sargassum Weed	0.0	0.7	4.1	99	47.0	86	80.6	55	80.3
Surfgrass	Surf Grass	79.0	78.1	66.5	50	100.0	50	100.0	50	100.0
Boa Kelp	Aggregating Anemone	0.0	0.0	0	99	10.6	99	22.4	99	23.3
Boa Kelp	Bare Substrate	2.2	1.2	4.8	52	80.5	68	81.1	50	84.5
Boa Kelp	Boa Kelp	11.5	8.5	8.1	58	81.2	63	80.1	61	80.9
Boa Kelp	Other Biota	4.1	1.1	8.1	69	81.0	80	80.3	50	98.7
Boa Kelp	Red Algal Turf	23.3	15.4	41.3	50	100.0	50	97.1	50	100.0
Boa Kelp	Sargassum Weed	0.1	0.0	2.4	99	27.9	99	23.7	60	80.5
Boa Kelp	Surf Grass	42.5	62.4	20.5	50	100.0	50	100.0	50	99.5
Red Algal Turf	Aggregating Anemone	0.5	0.4	0.9	55	80.9	72	80.5	50	97.5
Red Algal Turf	Bare Substrate	0.6	7.8	4.4	59	80.4	50	97.4	50	84.9
Red Algal Turf	Boa Kelp	0.2	0.4	0	99	52.5	99	74.5	99	
Red Algal Turf	Other Biota	0.1	0.2	0.2	99	68.0	99	67.9	99	64.4
Red Algal Turf	Red Algal Turf	84.4	72.3	88.5	50	100.0	50	100.0	50	100.0
Red Algal Turf	Sargassum Weed	0.0	0.1	0	99	16.7	99	55.9	99	23.0
Red Algal Turf	Surf Grass	8.8	12.3	2.1	64	80.4	50	93.5	70	80.9

Table 3. Sample size (n=number of surveys in After period) required to detect 50% changes in percent cover of taxa sampled with line transects in Before vs. After comparisons with a significance level of 5%.

		Zone I			II			III		
Plot Type	Taxon	Mean % cover	n	power	Mean % cover	n	power	Mean % cover	n	power
Surfgrass	Aggregating Anemone	0.0	21		0.0	21		0.0	21	6
Surfgrass	Bare Substrate	2.4	12	80	2.3	21	56	6.2	5	82
Surfgrass	Boa Kelp	0.5	21	24	2.4	21	51	0.6	21	41
Surfgrass	Other Biota	0.2	21	26	1.6	21	65	0.3	21	23
Surfgrass	Red Algal Turf	14.0	2	95	8.2	2	95	15.8	2	100
Surfgrass	Sargassum Weed	0.0	21	16	0.7	21	38	4.1	21	73
Surfgrass	Surf Grass	79.1	2	100	78.1	2	100	66.5	2	100
Boa Kelp	Aggregating Anemone	0.0	21	6	0.0	21	9	0.0	21	10
Boa Kelp	Bare Substrate	2.2	21	77	1.2	21	55	4.8	17	81
Boa Kelp	Boa Kelp	11.5	21	69	8.5	21	61	8.1	21	64
Boa Kelp	Other Biota	4.1	21	54	1.1	21	42	8.1	2	86
Boa Kelp	Red Algal Turf	23.3	2	98	15.4	2	81	41.3	2	100
Boa Kelp	Sargassum Weed	0.1	21	11	0.0	21	10	2.4	21	65
Boa Kelp	Surf Grass	42.5	2	98	62.4	2	99	20.5	2	91
Red Algal Turf	Aggregating Anemone	0.5	21	73	0.4	21	50	0.9	2	83
Red Algal Turf	Bare Substrate	0.6	21	67	7.8	2	82	4.4	16	81
Red Algal Turf	Boa Kelp	0.2	21	18	0.4	21	26	0.0	21	
Red Algal Turf	Other Biota	0.1	21	23	0.2	21	23	0.2	21	22
Red Algal Turf	Red Algal Turf	84.4	2	100	72.3	2	100	88.5	2	100
Red Algal Turf	Sargassum Weed	0.0	21	8	0.1	21	19	0.0	21	10
Red Algal Turf	Surf Grass	8.8	21	60	12.3	7	81	2.1	21	53.5

Table 4 . Power to detect 50% changes in percent cover of taxa sampled in Photo Plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I		Zone II		Zone III	
Plot Type	Taxon	Mean	Power	Mean	Power	Mean	Power
Acorn Barnacles	Anthopleura	0.01	7	0.02	6	0.01	6
Acorn Barnacles	Chthamalus/Balanus	4.82	70	11.63	100	22.46	96
Acorn Barnacles	Coralline crusts	0.00	6	0.00		0.00	6
Acorn Barnacles	Erect corallines	0.01	7	0.00	6	0.00	6
Acorn Barnacles	Miscellaneous invertebrates	0.00	8	0.00	6	0.00	6
Acorn Barnacles	Mytilus	0.41	87	0.73	68	0.00	6
Acorn Barnacles	Non-coralline crusts	0.13	8	0.02	6	0.00	6
Acorn Barnacles	Old Category: Bare Substrate	32.33	98	26.71	99	32.83	100
Acorn Barnacles	Old Category: Other Animals	2.39	74	4.14	68	2.57	66
Acorn Barnacles	Old Category: Other Plants	24.42	92	22.97	95	11.03	92
Acorn Barnacles	Other brown algae	0.00		0.00		0.00	
Acorn Barnacles	Other red algae	0.16	8	0.03	6	0.01	6
Acorn Barnacles	Pelvetia	0.01	14	1.34	83	0.86	100
Acorn Barnacles	Phragmatopoma	0.00		0.00		0.00	6
Acorn Barnacles	Pollicipes	0.28	34	0.00	8	0.00	
Acorn Barnacles	Rock	0.15	8	0.02	6	0.01	6
Acorn Barnacles	Tetraclita	6.86	97	8.84	98	12.64	100
Acorn Barnacles	Turf (low filamentous)	0.00		0.01	6	0.00	6
Acorn Barnacles	Ulva/Enteromorpha	0.00	6	0.00	6	0.00	6
Acorn Barnacles	Unidentified	0.00	6	0.00		0.00	6
Acorn Barnacles	Unidentified invertebrates	0.00		0.00		0.00	
Gooseneck Barnacles	Anthopleura	0.00	6	0.01	6	0.00	6
Gooseneck Barnacles	Chthamalus/Balanus	1.54	30	0.80	20	23.26	98
Gooseneck Barnacles	Coralline crusts	0.96	8	0.18	6	0.01	6
Gooseneck Barnacles	Erect corallines	0.00		0.00		0.00	
Gooseneck Barnacles	Miscellaneous invertebrates	0.04	8	0.01	6	0.01	6
Gooseneck Barnacles	Mytilus	0.02	10	0.10	53	0.02	16
Gooseneck Barnacles	Non-coralline crusts	0.25	8	0.08	6	0.02	6
Gooseneck Barnacles	Old Category: Bare Substrate	53.21	40	64.23	72	55.89	73
Gooseneck Barnacles	Old Category: Other Animals	0.45	22	1.33	40	0.59	34
Gooseneck Barnacles	Old Category: Other Plants	6.50	29	7.38	44	1.43	32

Table 4 (continued). Power to detect 50% changes in percent cover of taxa sampled in Photo Plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I		Zone II		Zone III	
Plot Type	Taxon	Mean	Power	Mean	Power	Mean	Power
Gooseneck Barnacles	Other brown algae	0.00		0.00		0.00	
Gooseneck Barnacles	Other red algae	0.00		0.00		0.00	
Gooseneck Barnacles	Pelvetia	0.00	6	0.00	6	0.00	
Gooseneck Barnacles	Phragmatopoma	0.00		0.00		0.00	
Gooseneck Barnacles	Pollicipes	9.58	99	9.64	100	3.66	100
Gooseneck Barnacles	Rock	2.89	8	0.78	6	0.44	6
Gooseneck Barnacles	Tetraclita	0.00	6	0.00	6	0.00	6
Gooseneck Barnacles	Turf (low filamentous)	0.00		0.00		0.00	
Gooseneck Barnacles	Ulva/Enteromorpha	0.01	8	0.00	6	0.00	
Gooseneck Barnacles	Unidentified	0.00		0.00		0.13	8
Gooseneck Barnacles	Unidentified invertebrates	0.00	6	0.00		0.00	
Mussels	Anthopleura	0.00	6	0.00	6	0.03	6
Mussels	Chthamalus/Balanus	0.13	20	0.65	41	18.99	66
Mussels	Coralline crusts	0.00		0.00	6	0.00	
Mussels	Erect corallines	0.04	8	0.12	6	0.00	6
Mussels	Miscellaneous invertebrates	0.00	7	0.00	6	0.00	6
Mussels	Mytilus	13.62	100	3.85	31	7.12	42
Mussels	Non-coralline crusts	0.10	8	0.00	6	0.00	6
Mussels	Old Category: Bare Substrate	25.32	98	16.59	100	38.50	99
Mussels	Old Category: Other Animals	1.32	83	1.03	60	3.26	93
Mussels	Old Category: Other Plants	27.52	98	60.46	100	8.62	86
Mussels	Other brown algae	0.00		0.00		0.00	
Mussels	Other red algae	0.05	8	0.05	6	0.01	6
Mussels	Pelvetia	0.00	6	0.00	14	0.00	10
Mussels	Phragmatopoma	0.00		0.00	6	0.00	
Mussels	Pollicipes	8.96	100	0.00	6	0.00	
Mussels	Rock	0.14	8	0.00	6	0.00	6
Mussels	Tetraclita	0.10	47	0.61	34	4.24	80
Mussels	Turf (low filamentous)	0.00		0.00	6	0.01	6
Mussels	Ulva/Enteromorpha	0.00	6	0.00	6	0.00	6
Mussels	Unidentified	0.00		0.00	6	0.00	6

Table 4 (continued). Power to detect 50% changes in percent cover of taxa sampled in Photo Plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I		Zone II		Zone III	
Plot Type	Taxon	Mean	Power	Mean	Power	Mean	Power
Mussels	Unidentified invertebrates	0.00		0.00		0.00	
Rockweed	Anthopleura	0.00		0.00		0.00	
Rockweed	Chthamalus/Balanus	0.11	23	0.11	37	0.54	55
Rockweed	Coralline crusts	0.00	6	0.00	6	0.00	
Rockweed	Erect corallines	0.03	8	0.01	6	0.01	6
Rockweed	Miscellaneous invertebrates	0.00	6	0.00		0.00	
Rockweed	Mytilus	0.00		0.00		0.00	
Rockweed	Non-coralline crusts	0.05	8	0.02	6	0.00	6
Rockweed	Old Category: Bare Substrate	6.39	93	6.41	97	3.42	95
Rockweed	Old Category: Other Animals	0.03	20	0.02	16	0.42	19
Rockweed	Old Category: Other Plants	23.62	98	18.52	100	14.11	96
Rockweed	Other brown algae	0.00		0.00	6	0.00	
Rockweed	Other red algae	0.13	8	0.00	6	0.02	6
Rockweed	Pelvetia	58.56	100	69.16	100	72.80	100
Rockweed	Phragmatopoma	0.00	6	0.00	6	0.01	6
Rockweed	Pollicipes	0.00		0.00		0.00	
Rockweed	Rock	0.00	6	0.00	6	0.00	6
Rockweed	Tetraclita	0.00	9	0.00	6	0.02	17
Rockweed	Turf (low filamentous)	0.01	6	0.01	6	0.00	6
Rockweed	Ulva/Enteromorpha	0.00	8	0.00		0.00	6
Rockweed	Unidentified	0.00		0.00		0.00	
Rockweed	Unidentified invertebrates	0.00		0.00		0.00	

1

Table 5. Percent changes in Before/After comparisons detectable with power of 80% and significance level (alpha) = 0.05.

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	% Change	Power	Mean	% Change	Power	Mean	% Change	Power
Acorn Barnacles	Anthopleura	0.01	99	14	0.02	99	27	0.01	99	23
Acorn Barnacles	Chthamalus/Balanus	4.82	56	79	11.63	50	100	22.46	50	100
Acorn Barnacles	Coralline crusts	0.00	99	10	0.00	99		0.00	99	17
Acorn Barnacles	Erect corallines	0.01	99	13	0.00	99	16	0.00	99	16
Acorn Barnacles	Miscellaneous invertebrates	0.00	99	16	0.00	99	11	0.00	99	11
Acorn Barnacles	Mytilus	0.41	50	100	0.73	73	80	0.00	99	11
Acorn Barnacles	Non-coralline crusts	0.13	99	16	0.02	99	29	0.00	99	23
Acorn Barnacles	Old Category: Bare Substrate	32.33	50	100	26.71	50	100	32.83	50	100
Acorn Barnacles	Old Category: Other Animals	2.39	50	100	4.14	50	100	2.57	50	100
Acorn Barnacles	Old Category: Other Plants	24.42	50	100	22.97	50	100	11.03	50	100
Acorn Barnacles	Other brown algae	0.00	99		0.00	99		0.00	99	
Acorn Barnacles	Other red algae	0.16	99	17	0.03	99	25	0.01	99	20
Acorn Barnacles	Pelvetia	0.01	99	40	1.34	54	80	0.86	50	100
Acorn Barnacles	Phragmatopoma	0.00	99		0.00	99		0.00	99	11
Acorn Barnacles	Pollicipes	0.28	91	80	0.00	99	17	0.00	99	
Acorn Barnacles	Rock	0.15	99	17	0.02	99	33	0.01	99	24
Acorn Barnacles	Tetraclita	6.86	50	100	8.84	50	100	12.64	50	100
Acorn Barnacles	Turf (low filamentous)	0.00	99		0.01	99	16	0.00	99	11
Acorn Barnacles	Ulva/Enteromorpha	0.00	99	10	0.00	99	21	0.00	99	11
Acorn Barnacles	Unidentified	0.00	99	10	0.00	99		0.00	99	11
Acorn Barnacles	Unidentified invertebrates	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Anthopleura	0.00	99	10	0.01	99	15	0.00	99	11
Gooseneck Barnacles	Chthamalus/Balanus	1.54	98	79	0.80	63	80	23.01	50	100
Gooseneck Barnacles	Coralline crusts	0.96	99	16	0.18	99	36	0.01	99	11
Gooseneck Barnacles	Erect corallines	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Miscellaneous invertebrates	0.04	99	17	0.01	99	22	0.01	99	23
Gooseneck Barnacles	Mytilus	0.02	99	27	0.10	96	80	0.02	99	39
Gooseneck Barnacles	Non-coralline crusts	0.25	99	17	0.08	99	34	0.02	99	17
Gooseneck Barnacles	Old Category: Bare Substrate	53.21	82	80	64.23	50	100	55.70	50	100
Gooseneck Barnacles	Old Category: Other Animals	0.45	99	64	1.33	50	100	0.58	50	99

Table 5 (continued). Percent changes in Before/After comparisons detectable with power of 80% and significance level (alpha) = 0.05.

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	% Change	Power	Mean	% Change	Power	Mean	% Change	Power
Gooseneck Barnacles	Old Category: Other Plants	6.50	99	79	7.38	50	100	1.48	81	80
Gooseneck Barnacles	Other brown algae	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Other red algae	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Pelvetia	0.00	99	10	0.00	99	11	0.00	99	
Gooseneck Barnacles	Phragmatopoma	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Pollicipes	9.58	50	100	9.64	50	100	3.65	50	100
Gooseneck Barnacles	Rock	2.89	99	17	0.78	99	40	0.48	99	42
Gooseneck Barnacles	Tetraclita	0.00	99	10	0.00	99	11	0.00	99	11
Gooseneck Barnacles	Turf (low filamentous)	0.00	99		0.00	99		0.00	99	
Gooseneck Barnacles	Ulva/Enteromorpha	0.01	99	15	0.00	99	11	0.00	99	
Gooseneck Barnacles	Unidentified	0.00	99		0.00	99		0.13	99	53
Gooseneck Barnacles	Unidentified invertebrates	0.00	99	10	0.00	99		0.00	99	
Mussels	Anthopleura	0.00	99	10	0.00	99	11	0.03	99	33
Mussels	Chthamalus/Balanus	0.13	99	59	0.65	70	79	18.99	50	100
Mussels	Coralline crusts	0.00	99		0.00	99	11	0.00	99	
Mussels	Erect corallines	0.04	99	17	0.12	99	34	0.00	99	15
Mussels	Miscellaneous invertebrates	0.00	99	14	0.00	99	11	0.00	99	17
Mussels	Mytilus	13.62	50	100	3.85	50	100	7.12	50	100
Mussels	Non-coralline crusts	0.10	99	17	0.00	99	27	0.00	99	16
Mussels	Old Category: Bare Substrate	25.32	50	100	16.59	50	100	38.50	50	100
Mussels	Old Category: Other Animals	1.32	50	100	1.03	50	100	3.26	50	100
Mussels	Old Category: Other Plants	27.52	50	100	60.46	50	100	8.62	50	100
Mussels	Other brown algae	0.00	99		0.00	99		0.00	99	
Mussels	Other red algae	0.05	99	15	0.05	99	32	0.01	99	21
Mussels	Pelvetia	0.00	99	10	0.00	99	36	0.00	99	23
Mussels	Phragmatopoma	0.00	99		0.00	99	11	0.00	99	
Mussels	Pollicipes	8.96	50	100	0.00	99	17	0.00	99	
Mussels	Rock	0.14	99	17	0.00	99	17	0.00	99	28
Mussels	Tetraclita	0.10	74	80	0.61	78	79	4.24	50	100
Mussels	Turf (low filamentous)	0.00	99		0.00	99	16	0.01	99	28
Mussels	Ulva/Enteromorpha	0.00	99	10	0.00	99	11	0.00	99	11

Table 5 (continued). Percent changes in Before/After comparisons detectable with power of 80% and significance level (alpha) = 0.05.

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	% Change	Power	Mean	% Change	Power	Mean	% Change	Power
Mussels	Unidentified	0.00	99		0.00	99	11	0.00	99	11
Mussels	Unidentified invertebrates	0.00	99		0.00	99		0.00	99	
Rockweed	Anthopleura	0.00	99		0.00	99		0.00	99	
Rockweed	Chthamalus/Balanus	0.11	99	68	0.11	81	79	0.54	57	79
Rockweed	Coralline crusts	0.00	99	10	0.00	99	11	0.00	99	
Rockweed	Erect corallines	0.03	99	17	0.01	99	22	0.01	99	23
Rockweed	Miscellaneous invertebrates	0.00	99	10	0.00	99		0.00	99	
Rockweed	Mytilus	0.00	99		0.00	99		0.00	99	
Rockweed	Non-coralline crusts	0.05	99	17	0.02	99	28	0.00	99	23
Rockweed	Old Category: Bare Substrate	6.39	50	100	6.39	50	100	3.42	50	100
Rockweed	Old Category: Other Animals	0.03	99	61	0.02	99	61	0.42	99	97
Rockweed	Old Category: Other Plants	23.62	50	100	18.43	50	100	14.11	50	100
Rockweed	Other brown algae	0.00	99		0.00	99	17	0.00	99	
Rockweed	Other red algae	0.13	99	16	0.00	99	22	0.02	99	31
Rockweed	Pelvetia	58.56	50	100	69.25	99		72.80	99	
Rockweed	Phragmatopoma	0.00	99	10	0.00	99	16	0.01	99	25
Rockweed	Pollicipes	0.00	99		0.00	99		0.00	99	
Rockweed	Rock	0.00	99	10	0.00	99	11	0.00	99	11
Rockweed	Tetraclita	0.00	99	20	0.00	99	11	0.02	99	63
Rockweed	Turf (low filamentous)	0.01	99	10	0.01	99	32	0.00	99	15
Rockweed	Ulva/Enteromorpha	0.00	99	17	0.00	99		0.00	99	22
Rockweed	Unidentified	0.00	99		0.00	99		0.00	99	
Rockweed	Unidentified invertebrates	0.00	99		0.00	99		0.00	99	

Table 6. Sample size (number of surveys in After period) required to detect 50% changes in percent cover of taxa sampled in Photo plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	n	Power	Mean	n	Power	Mean	n	Power
Acorn Barnacles	Anthopleura	0.01	20	10	0.02	20	8	0.01	20	8
Acorn Barnacles	Chthamalus/Balanus	4.82	6	81	11.63	1	100	22.46	1	97
Acorn Barnacles	Coralline crusts	0.00	20	8	0.00	20		0.00	20	8
Acorn Barnacles	Erect corallines	0.01	20	9	0.00	20	8	0.00	20	8
Acorn Barnacles	Miscellaneous invertebrates	0.00	20	11	0.00	20	8	0.00	20	8
Acorn Barnacles	Mytilus	0.41	1	88	0.73	7	81	0.00	20	8
Acorn Barnacles	Non-coralline crusts	0.13	20	11	0.02	20	8	0.00	20	8
Acorn Barnacles	Old Category: Bare Substrate	32.33	1	99	26.71	1	100	32.83	1	100
Acorn Barnacles	Old Category: Other Animals	2.39	3	80	4.14	6	80	2.57	7	80
Acorn Barnacles	Old Category: Other Plants	24.42	1	93	22.97	1	96	11.03	1	94
Acorn Barnacles	Other brown algae	0.00	20		0.00	20		0.00	20	
Acorn Barnacles	Other red algae	0.16	20	11	0.03	20	8	0.01	20	8
Acorn Barnacles	Pelvetia	0.01	20	23	1.34	1	85	0.86	1	100
Acorn Barnacles	Phragmatopoma	0.00	20		0.00	20		0.00	20	8
Acorn Barnacles	Pollicipes	0.28	20	60	0.00	20	11	0.00	20	
Acorn Barnacles	Rock	0.15	20	11	0.02	20	8	0.01	20	8
Acorn Barnacles	Tetraclita	6.86	1	98	8.84	1	99	12.64	1	100
Acorn Barnacles	Turf (low filamentous)	0.00	20		0.01	20	8	0.00	20	8
Acorn Barnacles	Ulva/Enteromorpha	0.00	20	8	0.00	20	8	0.00	20	8
Acorn Barnacles	Unidentified	0.00	20	8	0.00	20		0.00	20	8
Acorn Barnacles	Unidentified invertebrates	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Anthopleura	0.00	20	11	0.01	20	11	0.00	20	11
Gooseneck Barnacles	Chthamalus/Balanus	1.54	12	80	0.80	20	69	23.26	1	100
Gooseneck Barnacles	Coralline crusts	0.96	20	19	0.18	20	11	0.01	20	11
Gooseneck Barnacles	Erect corallines	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Miscellaneous invertebrates	0.04	20	20	0.01	20	11	0.01	20	11
Gooseneck Barnacles	Mytilus	0.02	20	32	0.10	1	89	0.02	20	56
Gooseneck Barnacles	Non-coralline crusts	0.25	20	20	0.08	20	11	0.02	20	11
Gooseneck Barnacles	Old Category: Bare Substrate	53.21	3	81	64.23	1	98	55.89	1	98
Gooseneck Barnacles	Old Category: Other Animals	0.45	20	74	1.33	3	81	0.59	8	81
Gooseneck Barnacles	Old Category: Other Plants	6.50	13	81	7.38	1	82	1.43	9	81

Table 6 (continued). Sample size (number of surveys in After period) required to detect 50% changes in percent cover of taxa sampled in Photo plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	n	Power	Mean	n	Power	Mean	n	Power
Gooseneck Barnacles	Other brown algae	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Other red algae	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Pelvetia	0.00	20	11	0.00	20	11	0.00	20	
Gooseneck Barnacles	Phragmatopoma	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Pollicipes	9.58	1	100	9.64	1	100	3.66	1	100
Gooseneck Barnacles	Rock	2.89	20	20	0.78	20	11	0.44	20	11
Gooseneck Barnacles	Tetraclita	0.00	20	11	0.00	20	11	0.00	20	11
Gooseneck Barnacles	Turf (low filamentous)	0.00	20		0.00	20		0.00	20	
Gooseneck Barnacles	Ulva/Enteromorpha	0.01	20	18	0.00	20	11	0.00	20	
Gooseneck Barnacles	Unidentified	0.00	20		0.00	20		0.13	20	19
Gooseneck Barnacles	Unidentified invertebrates	0.00	20	11	0.00	20		0.00	20	
Mussels	Anthopleura	0.00	20	8	0.00	20	8	0.03	20	8
Mussels	Chthamalus/Balanus	0.13	20	36	0.65	20	70	18.99	8	81
Mussels	Coralline crusts	0.00	20		0.00	20	8	0.00	20	
Mussels	Erect corallines	0.04	20	11	0.12	20	8	0.00	20	8
Mussels	Miscellaneous invertebrates	0.00	20	10	0.00	20	8	0.00	20	8
Mussels	Mytilus	13.62	1	100	3.85	20	55	7.12	20	71
Mussels	Non-coralline crusts	0.10	20	11	0.00	20	8	0.00	20	8
Mussels	Old Category: Bare Substrate	25.32	1	98	16.59	1	100	38.50	1	99
Mussels	Old Category: Other Animals	1.32	1	84	1.03	12	81	3.26	1	94
Mussels	Old Category: Other Plants	27.52	1	99	60.46	1	100	8.62	1	88
Mussels	Other brown algae	0.00	20		0.00	20		0.00	20	
Mussels	Other red algae	0.05	20	10	0.05	20	8	0.01	20	8
Mussels	Pelvetia	0.00	20	8	0.00	20	24	0.00	20	15
Mussels	Phragmatopoma	0.00	20		0.00	20	8	0.00	20	
Mussels	Pollicipes	8.96	1	100	0.00	20	8	0.00	20	
Mussels	Rock	0.14	20	11	0.00	20	8	0.00	20	8
Mussels	Tetraclita	0.10	20	77	0.61	20	60	4.24	1	82
Mussels	Turf (low filamentous)	0.00	20		0.00	20	8	0.01	20	8
Mussels	Ulva/Enteromorpha	0.00	20	8	0.00	20	8	0.00	20	8
Mussels	Unidentified	0.00	20		0.00	20	8	0.00	20	8

Table 6 (continued). Sample size (number of surveys in After period) required to detect 50% changes in percent cover of taxa sampled in Photo plots in Before vs. After comparisons. Significance level (alpha) = 0.05

		Zone I			Zone II			Zone III		
Plot Type	Taxon	Mean	n	Power	Mean	n	Power	Mean	n	Power
Mussels	Unidentified invertebrates	0.00	20		0.00	20		0.00	20	
Rockweed	Anthopleura	0.00	20		0.00	20		0.00	20	
Rockweed	Chthamalus/Balanus	0.11	20	42	0.11	20	64	0.54	15	80
Rockweed	Coralline crusts	0.00	20	8	0.00	20	8	0.00	20	
Rockweed	Erect corallines	0.03	20	11	0.01	20	8	0.01	20	8
Rockweed	Miscellaneous invertebrates	0.00	20	8	0.00	20		0.00	20	
Rockweed	Mytilus	0.00	20		0.00	20		0.00	20	
Rockweed	Non-coralline crusts	0.05	20	11	0.02	20	8	0.00	20	8
Rockweed	Old Category: Bare Substrate	6.39	1	94	6.41	1	98	3.42	1	96
Rockweed	Old Category: Other Animals	0.03	20	37	0.02	20	28	0.42	20	34
Rockweed	Old Category: Other Plants	23.62	1	98	18.52	1	100	14.11	1	96
Rockweed	Other brown algae	0.00	20		0.00	20	8	0.00	20	
Rockweed	Other red algae	0.13	20	11	0.00	20	8	0.02	20	8
Rockweed	Pelvetia	58.56	1	100	69.16	1	100	72.80	1	100
Rockweed	Phragmatopoma	0.00	20	8	0.00	20	8	0.01	20	8
Rockweed	Pollicipes	0.00	20		0.00	20		0.00	20	
Rockweed	Rock	0.00	20	8	0.00	20	8	0.00	20	8
Rockweed	Tetraclita	0.00	20	13	0.00	20	8	0.02	20	29
Rockweed	Turf (low filamentous)	0.01	20	8	0.01	20	8	0.00	20	8
Rockweed	Ulva/Enteromorpha	0.00	20	11	0.00	20		0.00	20	8
Rockweed	Unidentified	0.00	20		0.00	20		0.00	20	
Rockweed	Unidentified invertebrates	0.00	20		0.00	20		0.00	20	

Table 7. Power to detect 50% decreases or increases in owl limpet (*Lottia gigantean*) densities for Before/After comparisons, alpha = 0.05.

Mean Number per acre			Power				
I	II	III	I	II	III	Mean	Std
13	8.45	9.91	100	100	100	100.0	0.0

Table 8. Effect size necessary for 80% power to detect decreases or increases in owl limpet (*Lottia gigantea*) densities for Before/After comparisons, alpha = 0.05.

Mean Number per acre			I		II		III			
I	II	III	% □	power	% □	power	% □	power	Mean	Std
13	8.45	9.91	6	87	8	80	9	87	8	1.2

Table 9. Number of surveys in After period needed to detect 50% decreases or increases in Lottia densities with 80% power for Before/After comparisons, alpha = 0.05.

Mean Number per acre			I		II		III			
I	II	III	n	power	n	power	n	power	Mean	Std
13	8.45	9.91	1	100	1	100	1	100	1	0.0

Table 10. Power to detect 50% decreases or increases in bird densities for Before/After comparisons, alpha = 0.05.

	Mean Number per acre			Power				
Category	I	II	III	I	II	III	Mean	Std
Other	0.00	0.00	0.01	10.5	13.4	19.6	14.5	3.8
Sea Birds	0.61	0.92	2.32	100	100	100	100.0	0.0
Shore Birds	0.49	1.19	0.62	100	100	100	100.0	0.0
Wading Birds	0.17	0.26	0.23	99.8	100	100	99.9	0.1

Table 11. Effect size necessary for 80% power to detect decreases or increases in bird densities for Before/After comparisons, alpha = 0.05.

	Mean Number per acre			I		II		III	
Category	I	II	III	% □	power	% □	power	% □	power
Other	0.00	0.00	0.01	-99	27.12	-99	38.35	-99	58.76
Sea Birds	0.61	0.92	2.32	-19	83.46	-16	80.13	-15	83.12
Shore Birds	0.49	1.19	0.62	-24	81.81	-16	83.98	-20	82.71
Wading Birds	0.17	0.26	0.23	-29	80.11	-23	81.35	-17	79.9

Table 12. Sample size necessary to detect 50% decreases or increases in bird densities with 80% power for Before/After comparisons, alpha = 0.05.

	Mean Number per acre			I		II		III	
Category	I	II	III	n	power	n	power	n	power
Other	0.00	0.00	0.01	456	16	456	22	456	34
Sea Birds	0.61	0.92	2.32	1	100	1	100	1	100
Shore Birds	0.49	1.19	0.62	1	100	1	100	1	100
Wading Birds	0.17	0.26	0.23	1	100	1	100	1	100

Table 13. Power to detect 50% decreases or increases in visitor densities for Before/After comparisons, alpha = 0.05.

Mean Number per acre			Power				
I	II	III	I	II	III	Mean	Std
9.4	1.8	0.2	100	100	100	100.0	0.0

Table 14. Effect size necessary for 80% power to detect decreases or increases in visitor densities for Before/After comparisons, alpha = 0.05.

Mean Number per acre			I		II		III			
I	II	III	% □	power	% □	power	% □	power	Mean	Std
9.4	1.8	0.2	7	100	15	100	36	100	19	12.2

Table 15. Number of surveys in After period needed to detect 50% decreases or increases in visitor densities with 80% power for Before/After comparisons, alpha = 0.05.

Mean Number per acre			I		II		III			
I	II	III	n	power	n	power	n	power	Mean	Std
9.4	1.8	0.2	1	100	1	100	1	100	1	0.0

Table 16. Summary of tests for trends and non-additivity for taxa sampled in line transects. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone (I=far impact, II=near impact, III=control).

Transect Type	Taxon	Comparison	Trends 1=yes, 0=no	Non-additive	Trends or Non-additive
Surfgrass	Bare Substrate	I-II	0	0	0
Surf grass	Boa Kelp	I-II	1	1	1
Surfgrass	Other Biota	I-II	0	1	1
Surfgrass	Red Algal Turf	I-II	1	0	1
Surfgrass	Sargassum Weed	I-II	1	1	1
Surfgrass	Surf Grass	I-II	0	0	0
Surfgrass	Aggregating Anemone	I-III			
Surfgrass	Bare Substrate	I-III	0	1	1
Surfgrass	Boa Kelp	I-III	0	0	0
Surfgrass	Other Biota	I-III	1	1	1
Surfgrass	Red Algal Turf	I-III	0	0	0
Surfgrass	Sargassum Weed	I-III	0	1	1
Surfgrass	Surf Grass	I-III	0	0	0
Surfgrass	Aggregating Anemone	II-III			
Surfgrass	Bare Substrate	II-III	0	0	0
Surfgrass	Boa Kelp	II-III	1	1	1
Surfgrass	Other Biota	II-III	1	0	1
Surfgrass	Red Algal Turf	II-III	1	0	1
Surfgrass	Sargassum Weed	II-III	1	1	1
Surfgrass	Surf Grass	II-III	1	0	1
Boa Kelp	Aggregating Anemone	I-II	0	1	1
Boa Kelp	Bare Substrate	I-II	0	0	0
Boa Kelp	Boa Kelp	I-II	1	0	1
Boa Kelp	Other Biota	I-II	0	0	0
Boa Kelp	Red Algal Turf	I-II	0	0	0
Boa Kelp	Sargassum Weed	I-II	0	1	1
Boa Kelp	Surf Grass	I-II	1	1	1
Boa Kelp	Aggregating Anemone	I-III	1	0	0
Boa Kelp	Bare Substrate	I-III	0	0	0
Boa Kelp	Boa Kelp	I-III	1	0	1
Boa Kelp	Other Biota	I-III	0	0	0
Boa Kelp	Red Algal Turf	I-III	1	1	1
Boa Kelp	Sargassum Weed	I-III	0	1	1
Boa Kelp	Surf Grass	I-III	1	0	1
Boa Kelp	Aggregating Anemone	II-III	1	1	1
Boa Kelp	Bare Substrate	II-III	0	0	0
Boa Kelp	Boa Kelp	II-III	0	0	0
Boa Kelp	Other Biota	II-III	0	0	0

Table 16 (continued). Summary of tests for trends and non-additivity for taxa sampled in line transects. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone (I=far impact, II=near impact, III=control).

Transect Type	Taxon	Comparison	Trends 1=yes, 0=no	Non-additive	Trends or Non-additive
Boa Kelp	Red Algal Turf	II-III	1	1	1
Boa Kelp	Sargassum Weed	II-III	0	1	1
Boa Kelp	Surf Grass	II-III	0	1	1
Red Algal Turf	Aggregating Anemone	I-II	1	0	1
Red Algal Turf	Bare Substrate	I-II	1	1	1
Red Algal Turf	Boa Kelp	I-II	1	0	1
Red Algal Turf	Other Biota	I-II	0	1	1
Red Algal Turf	Red Algal Turf	I-II	0	1	1
Red Algal Turf	Sargassum Weed	I-II	0	1	1
Red Algal Turf	Surf Grass	I-II	1	1	1
Red Algal Turf	Aggregating Anemone	I-III	1	1	1
Red Algal Turf	Bare Substrate	I-III	0	1	1
Red Algal Turf	Boa Kelp	I-III	0	1	1
Red Algal Turf	Other Biota	I-III	1	1	1
Red Algal Turf	Red Algal Turf	I-III	0	1	1
Red Algal Turf	Sargassum Weed	I-III	0	1	0
Red Algal Turf	Surf Grass	I-III	0	0	0
Red Algal Turf	Aggregating Anemone	II-III	1	1	1
Red Algal Turf	Bare Substrate	II-III	1	1	1
Red Algal Turf	Boa Kelp	II-III	1	1	1
Red Algal Turf	Other Biota	II-III	1	1	1
Red Algal Turf	Red Algal Turf	II-III	0	0	0
Red Algal Turf	Sargassum Weed	II-III	0	1	1
Red Algal Turf	Surf Grass	II-III	1	1	1
	Cases failing to pass assumptions		28	34	42
	Total cases		60	60	60

Table 17. Power to detect 50% change in percent cover of taxa sampled on transects. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

				Mean % Cover		
Transect Type	Taxon	Impact/Control		Impact	Control	Power
Surf grass	Bare Substrate	I	II	2.4	2.3	5
Surf grass	Surf Grass	I	II	79	78.1	5
Surf grass	Boa Kelp	I	III	0.5	0.6	5
Surf grass	Red Algal Turf	I	III	14	15.8	6
Surf grass	Surf Grass	I	III	79	66.5	30
Surf grass	Bare Substrate	II	III	2.3	6.2	24
Boa Kelp	Bare Substrate	I	II	2.2	1.2	12
Boa Kelp	Other Biota	I	II	4.1	1.1	12
Boa Kelp	Red Algal Turf	I	II	23.3	15.4	16
Boa Kelp	Aggregating Anemone	I	III	0	0	6
Boa Kelp	Bare Substrate	I	III	2.2	4.8	14
Boa Kelp	Other Biota	I	III	4.1	8.1	11
Boa Kelp	Bare Substrate	II	III	1.2	4.8	36
Boa Kelp	Boa Kelp	II	III	8.5	8.1	5
Boa Kelp	Other Biota	II	III	1.1	8.1	55
Red Algal Turf	Sargassum Weed	I	III	0	0	6
Red Algal Turf	Surf Grass	I	III	8.8	2.1	11
Red Algal Turf	Red Algal Turf	II	III	72.3	88.5	33

Table 18. Percent change in percent cover for 80% power for taxa sampled on transects. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

				Mean % Cover			
Transect Type	Taxon	Impact/Control		Impact	Control	% change	Power
Surfgrass	Bare Substrate	I	II	2.4	2.3	-72	5
Surf grass	Surf Grass	I	II	79	78.1	-91	5
Surf grass	Boa Kelp	I	III	0.5	0.6	-100	6
Surf grass	Red Algal Turf	I	III	14	15.8	-100	10
Surf grass	Surf Grass	I	III	79	66.5	-100	79
Surfgrass	Bare Substrate	II	III	2.3	6.2	-100	71
Boa Kelp	Bare Substrate	I	II	2.2	1.2	-100	35
Boa Kelp	Other Biota	I	II	4.1	1.1	-100	32
Boa Kelp	Red Algal Turf	I	II	23.3	15.4	-100	49
Boa Kelp	Aggregating Anemone	I	III	0	0	-100	9
Boa Kelp	Bare Substrate	I	III	2.2	4.8	-100	42
Boa Kelp	Other Biota	I	III	4.1	8.1	-100	31
Boa Kelp	Bare Substrate	II	III	1.2	4.8	-100	79
Boa Kelp	Boa Kelp	II	III	8.5	8.1	-98	5
Boa Kelp	Other Biota	II	III	1.1	8.1	-100	78
Red Algal Turf	Sargassum Weed	I	II	0	0.1	-100	37
Red Algal Turf	Surf Grass	I	II	8.8	12.3	-100	23
Red Algal Turf	Red Algal Turf	I	III	84.4	88.5	-100	11

Table 19. Sample size (number of surveys in After period) needed to detect a 50% change in differences in abundance between zones with 80% power for taxa sampled on transects. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

				Mean % Cover			
Transect Type	Taxon	Impact/Control		Impact	Control	n	Power
Surfgrass	Bare Substrate	I	II	2.4	2.3	100	5
Surfgrass	Surf Grass	I	II	79	78.1	100	6
Surfgrass	Boa Kelp	I	III	0.5	0.6	100	9
Surfgrass	Red Algal Turf	I	III	14	15.8	100	17
Surfgrass	Surf Grass	I	III	79	66.5	41	80
Surfgrass	Bare Substrate	II	III	2.3	6.2	52	80
Boa Kelp	Bare Substrate	I	II	2.2	1.2	100	68
Boa Kelp	Other Biota	I	II	4.1	1.1	100	64
Boa Kelp	Red Algal Turf	I	II	23.3	15.4	86	80
Boa Kelp	Aggregating Anemone	I	III	0	0	100	15
Boa Kelp	Bare Substrate	I	III	2.2	4.8	100	78
Boa Kelp	Other Biota	I	III	4.1	8.1	100	62
Boa Kelp	Bare Substrate	II	III	1.2	4.8	33	80
Boa Kelp	Boa Kelp	II	III	8.5	8.1	100	6
Boa Kelp	Other Biota	II	III	1.1	8.1	22	84
Red Algal Turf	Sargassum Weed	I	II	0	0.1	100	71
Red Algal Turf	Surf Grass	I	II	8.8	12.3	100	48
Red Algal Turf	Red Algal Turf	I	III	84.4	88.5	100	20

Table 20. Summary of tests for non-additivity and trends for taxa sampled in Photo Plots. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone (I=far impact, II=near impact, III=control). Comp. = Comparison.

Plot Type	Taxon	Comparison	(A) Trends	(B) Non-additive	(A) or (B)
Acorn Barnacles	Chthamalus/Balanus	III-I	0	1	1
Acorn Barnacles	Erect corallines	III-I	1	1	1
Acorn Barnacles	Miscellaneous invertebrates	III-I	1	1	1
Acorn Barnacles	Mytilus	III-I	1	1	1
Acorn Barnacles	Non-coralline crusts	III-I	1	1	1
Acorn Barnacles	Old Category: Bare Substrate	III-I	1	0	1
Acorn Barnacles	Old Category: Other Animals	III-I	0	0	0
Acorn Barnacles	Old Category: Other Plants	III-I	0	1	1
Acorn Barnacles	Other red algae	III-I	1	1	1
Acorn Barnacles	Pelvetia	III-I	0	1	1
Acorn Barnacles	Pollicipes	III-I	1	1	1
Acorn Barnacles	Rock	III-I	1	1	1
Acorn Barnacles	Tetraclita	III-I	1	1	1
Acorn Barnacles	Anthopleura	III-II	1	1	1
Acorn Barnacles	Chthamalus/Balanus	III-II	0	1	1
Acorn Barnacles	Erect corallines	III-II	1	1	1
Acorn Barnacles	Miscellaneous invertebrates	III-II	1	1	1
Acorn Barnacles	Mytilus	III-II	0	1	1
Acorn Barnacles	Non-coralline crusts	III-II	1	1	1
Acorn Barnacles	Old Category: Bare Substrate	III-II	1	0	1
Acorn Barnacles	Old Category: Other Animals	III-II	0	1	1
Acorn Barnacles	Old Category: Other Plants	III-II	0	1	1
Acorn Barnacles	Other red algae	III-II	1	1	1
Acorn Barnacles	Pelvetia	III-II	1	1	1

Acorn Barnacles	Rock	III-II	1	1	1
Acorn Barnacles	Tetraclita	III-II	1	1	1
Acorn Barnacles	Ulva/Enteromorpha	III-II	1	1	1
Acorn Barnacles	Anthopleura	I-II	1	1	1
Acorn Barnacles	Chthamalus/Balanus	I-II	0	1	1
Acorn Barnacles	Erect corallines	I-II	1	1	1
Acorn Barnacles	Mytilus	I-II	0	0	0
Acorn Barnacles	Non-coralline crusts	I-II	1	1	1
Acorn Barnacles	Old Category: Bare Substrate	I-II	0	0	0
Acorn Barnacles	Old Category: Other Animals	I-II	0	1	1
Acorn Barnacles	Old Category: Other Plants	I-II	0	0	0
Acorn Barnacles	Other red algae	I-II	1	1	1
Acorn Barnacles	Pelvetia	I-II	1	1	1
Acorn Barnacles	Pollicipes	I-II	1	1	1
Acorn Barnacles	Tetraclita	I-II	0	0	0
Acorn Barnacles	Ulva/Enteromorpha	I-II	1	1	1
Mussels	Anthopleura	III-I	1	1	1
Mussels	Chthamalus/Balanus	III-I	1	1	1
Mussels	Erect corallines	III-I	1	1	1
Mussels	Miscellaneous invertebrates	III-I	1	1	1
Mussels	Mytilus	III-I	1	1	1
Mussels	Non-coralline crusts	III-I	1	1	1

Table 20 (continued). Summary of tests for non-additivity and trends for taxa sampled in Photo Plots.

Plot Type	Taxon	Comparison	(A) Trends	(B) Non-additive	(A) or (B)
Mussels	Old Category: Bare Substrate	III-I	0	1	1
Mussels	Old Category: Other Animals	III-I	0	1	1
Mussels	Old Category: Other Plants	III-I	1	0	1
Mussels	Other red algae	III-I	1	1	1
Mussels	Pelvetia	III-I	0	1	1
Mussels	Pollicipes	III-I	1	1	1
Mussels	Rock	III-I	1	1	1
Mussels	Tetraclita	III-I	1	1	1
Mussels	Turf (low filamentous)	III-I	1	1	1

Mussels	Ulva/Enteromorpha	III-I	1	1	1
Mussels	Anthopleura	III-II	1	1	1
Mussels	Chthamalus/Balanus	III-II	1	1	1
Mussels	Erect corallines	III-II	1	1	1
Mussels	Miscellaneous invertebrates	III-II	1	1	1
Mussels	Mytilus	III-II	1	0	1
Mussels	Non-coralline crusts	III-II	1	1	1
Mussels	Old Category: Bare Substrate	III-II	0	1	1
Mussels	Old Category: Other Animals	III-II	1	0	1
Mussels	Old Category: Other Plants	III-II	0	1	1
Mussels	Other red algae	III-II	1	1	1
Mussels	Pelvetia	III-II	0	1	1
Mussels	Pollicipes	III-II	0	1	1
Mussels	Rock	III-II	1	1	1
Mussels	Tetraclita	III-II	1	1	1
Mussels	Turf (low filamentous)	III-II	1	1	1
Mussels	Ulva/Enteromorpha	III-II	1	1	1
Mussels	Anthopleura	I-II	1	1	1
Mussels	Chthamalus/Balanus	I-II	0	1	1
Mussels	Erect corallines	I-II	1	1	1
Mussels	Miscellaneous invertebrates	I-II	1	1	1
Mussels	Mytilus	I-II	1	1	1
Mussels	Non-coralline crusts	I-II	1	1	1
Mussels	Old Category: Bare Substrate	I-II	1	1	1
Mussels	Old Category: Other Animals	I-II	1	0	1
Mussels	Old Category: Other Plants	I-II	1	1	1
Mussels	Other red algae	I-II	1	1	1
Mussels	Pelvetia	I-II	1	0	1
Mussels	Pollicipes	I-II	1	1	1
Mussels	Rock	I-II	1	1	1
Mussels	Tetraclita	I-II	1	1	1
Mussels	Turf (low filamentous)	I-II	1	1	1
Rockweed	Chthamalus/Balanus	III-I	1	1	1
Rockweed	Old Category: Bare Substrate	III-I	1	0	1
Rockweed	Old Category: Other Animals	III-I	1	1	1
Rockweed	Old Category: Other Plants	III-I	0	1	1
Rockweed	Pelvetia	III-I	0	0	0
Rockweed	Tetraclita	III-I	1	1	1
Rockweed	Chthamalus/Balanus	III-II	1	1	1
Rockweed	Old Category: Bare Substrate	III-II	0	1	1

1

Table 20 (continued). Summary of tests for non-additivity and trends for taxa sampled in Photo Plots.

Plot Type	Taxon	Comparison	(A) Trends	(B) Non-additive	(A) or (B)
Rockweed	Old Category: Other Animals	III-II	1	1	1
Rockweed	Old Category: Other Plants	III-II	1	1	1
Rockweed	Pelvetia	III-II	0	0	0
Rockweed	Tetraclita	III-II	1	1	1
Rockweed	Chthamalus/Balanus	I-II	0	0	0
Rockweed	Old Category: Bare Substrate	I-II	1	0	1
Rockweed	Old Category: Other Animals	I-II	1	0	1
Rockweed	Old Category: Other Plants	I-II	1	0	1
Rockweed	Pelvetia	I-II	0	0	0
Rockweed	Tetraclita	I-II	0	1	1
	Number of cases failing to pass assumption		76	85	96
	Total number of cases		105	105	105

Table 21. Power to detect 50% change for taxa sampled in Photo Plots. Power was calculated for taxa with deltas passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

Plot Type	Taxon	Impact/Control		Mean % Cover Impact	Mean % Cover Control	Power
Acorn Barnacles	Mytilus	I	II	0.4	0.7	98
Acorn Barnacles	Old Category: Bare Substrate	I	II	32.3	26.7	96
Acorn Barnacles	Old Category: Other Plants	I	II	24.4	23.0	90
Acorn Barnacles	Tetraclita	I	II	6.9	8.8	99
Rockweed	Chthamalus/Balanus	I	II	0.1	0.1	24
Rockweed	Pelvetia	I	II	58.6	69.2	100
Acorn Barnacles	Old Category: Other Animals	I	III	2.4	2.6	77
Rockweed	Pelvetia	I	III	58.6	72.8	100
Rockweed	Pelvetia	II	III	69.2	72.8	100

Table 22. Percent change detectable with power of 80% for taxa sampled in Photo Plots. Power was calculated for taxa with deltas passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

Plot Type		Impact/Control		Mean % Cover Impact	Mean % Cover Control	% Change	Power
Acorn Barnacles	Mytilus	I	II	0.4	0.7	35	82
Acorn Barnacles	Old Category: Bare Substrate	I	II	32.3	26.7	38	81

Acorn Barnacles	Old Category: Other Plants	I	II	24.4	23.0	44	81
Acorn Barnacles	Tetraclita	I	II	6.9	8.8	32	80
Rockweed	Chthamalus/Balanus	I	II	0.1	0.1	99	69
Rockweed	Pelvetia	I	II	58.6	69.2	9	81
Acorn Barnacles	Old Category: Other Animals	I	III	2.4	2.6	53	81
Rockweed	Pelvetia	I	III	58.6	72.8	9	84
Rockweed	Pelvetia	II	III	69.2	72.8	9	82

Table 23. Sample size (number of surveys in After Period) required to detect 50% change with 80% power for taxa sampled in Photo Plots. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on 21 semi-annual surveys conducted from 1990 to 2000 on which samples were taken from each zone.

				Mean % Cover			
Plot Type	Taxon	Impact/Control		Impact	Control	n	Power
Acorn Barnacles	Mytilus	I	II	0.4	0.7	1	80
Acorn Barnacles	Old Category: Acorn Barnacles	I	II	32.3	26.7	1	80
Acorn Barnacles	Old Category: Other Plants	I	II	24.4	23.0	1	82
Acorn Barnacles	Tetraclita	I	II	6.9	8.8	1	81
Rockweed	Chthamalus/Balanus	I	II	0.1	0.1	29	51
Rockweed	Pelvetia	I	II	58.6	69.2	1	100
Acorn Barnacles	Old Category: Other Animals	I	III	2.4	2.6	1	81
Rockweed	Pelvetia	I	III	58.6	72.8	1	100
Rockweed	Pelvetia	II	III	69.16	72.8	1	100

Table 24. Power to detect a 50% change in the delta between Impact and Control from Before to After for Owl Limpet (*Lottia gigantea*) abundances sampled throughout zones I, II, and III. Power was calculated for comparisons passing tests for temporal trends and non-additivity. Data are based on ~20 surveys conducted from 1990 to 2000. A or T: Comparisons passing both additivity and trends tests are designated "0"; those failing either one are designated "1".

		Back-transformed Mean Number per Acre			
Impact	Control	Impact	Control	Power	A or T
I	III	14.5	12.1	5	0
II	III	9.6	12.1	17	1
I	II	14.5	9.6	59	1

Table 25. Change in differences in abundance between Impact and Control from Before to After detectable with power of 80% for Owl Limpet (*Lottia gigantea*) abundances sampled throughout zones I, II, and III. Power was calculated for comparisons passing tests for temporal trends and non-additivity. Data are based on ~ 20 surveys conducted from 1990 to 2000. A or T: Comparisons passing both additivity and trends tests are designated "0"; those failing either one are designated "1".

		Back-transformed Mean Number per Acre				
Impact	Control	Impact	Control	% change	Power	A or T
I	III	14.5	12.1	97	6	0
II	III	9.6	12.1	100	56	1
I	II	14.5	9.6	64	80	1

Table 26. Sample size (number of surveys in After period) needed to detect a 50% change in the difference in abundance between Impact and Control from Before to After with 80% power for Owl Limpets (*Lottia gigantea*) sampled throughout zones I, II, and III. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on ~ 20 surveys conducted from 1990 to 2000. A or T: Comparisons passing both additivity and trends tests are designated "0"; those failing either one are designated "1".

		Back-transformed Mean Number per Acre			
Impact	Control	Impact	Control	Surveys in After Period	Power
I	III	14.5	12.1	20	6
II	III	9.6	12.1	30	63
I	II	14.5	9.6	10	81

Table 27. Power to detect a 50% change in differences in abundance between Zone 1 and Zone 2 from Before to After for four categories of birds sampled throughout zones I, II, and III. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on ~456 bird censuses conducted from 1990 to 2000. A or T: deltas pass (0) or fail (1) tests for additivity or trends at p> 0.25.

			Back-transformed Mean Number per Acre			
Species Category	Impact	Control	Impact	Control	Power	A or T
Other	I	II	0.003	0.003	5	0
Sea Birds	I	II	0.615	0.920	56	1
Shore Birds	I	II	0.487	1.194	98	0
Wading Birds	I	II	0.174	0.258	37	1
Other	I	III	0.003	0.009	10	1
Sea Birds	I	III	0.615	2.325	100	1
Shore Birds	I	III	0.487	0.616	16	1
Wading Birds	I	III	0.174	0.232	27	1
Other	II	III	0.003	0.009	10	1
Sea Birds	II	III	0.920	2.325	96	1
Shore Birds	II	III	1.194	0.616	90	1
Wading Birds	II	III	0.258	0.232	9	1

Table 28. Change in differences in abundance between Impact and Control from Before to After detectable with power of 80% for four categories of birds sampled throughout zones I, II, and III. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on ~456 bird censuses conducted from 1990 to 2000. A or T: deltas pass (0) or fail (1) tests for additivity (A) or trends (T) at p> 0.25.

			Back-transformed Mean Number per Acre				
Species Category	Impact	Control	Impact	Control	% change	Power	A or T
Other	I	II	0.003	0.003	100	55	0
Sea Birds	I	II	0.615	0.920	18.3	80	1
Shore Birds	I	II	0.487	1.194	16.1	79	0
Wading Birds	I	II	0.174	0.258	21.6	80	1
Other	I	III	0.003	0.009	99.9	73	1
Sea Birds	I	III	0.615	2.325	15.1	79	1
Shore Birds	I	III	0.487	0.616	16.6	79	1
Wading Birds	I	III	0.174	0.232	17.6	80	1
Other	II	III	0.003	0.009	100	75	1
Sea Birds	II	III	0.920	2.325	13.8	79	1
Shore Birds	II	III	1.194	0.616	15.5	80	1
Wading Birds	II	III	0.258	0.232	17.7	80	1

Table 29. Sample size (number of surveys in After period) needed to detect a 50% change in the difference in abundance between Impact and Control from Before to After with 80% power for four categories of birds sampled throughout zones I, II, and III. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on ~456 bird censuses conducted from 1990 to 2000. A or T: deltas pass (0) or fail (1) tests for additivity or trends at p> 0.25.

			Back-transformed Mean Number per Acre				
Species Category	Impact	Control	Impact	Control	Surveys in After Period	Power	A or T
Other	I	II	0.003	0.003	456	6	0
Sea Birds	I	II	0.615	0.920	1	99	1
Shore Birds	I	II	0.487	1.194	1	100	0
Wading Birds	I	II	0.174	0.258	1	90	1
Other	I	III	0.003	0.009	456	48	1
Sea Birds	I	III	0.615	2.325	1	100	1
Shore Birds	I	III	0.487	0.616	456	79	1
Wading Birds	I	III	0.174	0.232	24	80	1
Other	II	III	0.003	0.009	456	42	1
Sea Birds	II	III	0.920	2.325	1	100	1
Shore Birds	II	III	1.194	0.616	1	100	1
Wading Birds	II	III	0.258	0.232	456	38	1

Table 30. Power to detect a 50% change in differences in abundance between Impact and Control from Before to After for number of people censused throughout zones I, II, and III. Power was calculated for comparisons passing tests for temporal trends and non-additivity. Data are based on ~529 people censuses conducted from 1990 to 2000.

		Back-transformed Mean Number per Acre			
Impact	Control	Impact	Control	Power	A or T
I	II	9.4	1.8	100	1
I	III	9.4	0.2	100	1
II	III	1.8	0.2	100	1

Table 31. Change in differences in abundance between Impact and Control from Before to After detectable with power of 80% for people censused throughout zones I, II, and III. Power was calculated for comparisons passing tests for temporal trends and non-additivity. Data are based on ~529 people censuses conducted from 1990 to 2000. Zone 1 is considered the impact site and Zone 2 the control.

		Back-transformed Mean Number per Acre				
Impaact	Control	Impact	Control	% change	Power	A or T
I	II	9.4	1.8	9.5	80	1
I	III	9.4	0.2	6.8	79	1
II	III	1.8	0.2	14.7	80	1

Table 32. Sample size (number of surveys in After period) needed to detect a 50% change in the difference in abundance between Impact and Control from Before to After with 80% power for people censused throughout zones I, II, and III. Power was calculated for taxa passing tests for temporal trends and non-additivity. Data are based on ~529 people censuses conducted from 1990 to 2000.

		Back-transformed Mean Number per Acre				
Impact	Control	Impact	Control	Surveys in After Period	Power	A or T
I	II	9.4	1.8	6	80	1
I	III	9.4	0.2	4	84	1
II	III	1.8	0.2	13	82	1

References

Box, G.E.P and G.C. Tiao. 1975. Intervention analysis with applications to economic and environmental problems. Journal of the American Statistical Association 70: 70-79.

Schroeter, S.C., J.D. Dixon, J. Kastendiek, R.O. Smith, and J.R. Bence. 1993. Detecting the ecological effects of environmental impacts: a case study of kelp forest invertebrates. Ecological Applications 3: 330-349.

Stewart Oaten, A. and J.R. Bence. 2001. Temporal and spatial variation in environmental impact analysis. Ecological Monographs 71(2): 305-339.

Appendix III. Mediterranean Conferences "MEDECOS" held over the past 30 years, topics addressed and resultant publications.

Year	Location	Subject	Resultant Publication
1971	Valdivia, Chile	Origin, Structure and Convergent and Divergent Evolution of Mediterranean Ecosystems and Biota	F. di Castri & H.A. Mooney editors, 1973. Mediterranean-Type Ecosystems: Structure & Function, Springer-Verlag.
1977	Stanford, CA, USA	Fire & Fuel Management	H.A. Mooney & C.E. Conrad editors, 1977. Proceedings of the Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems, U.S.D.A. Forest Service.
1980	Stellenbosch, South Africa	Role of Nutrients	F.J. Kruger, D.T. Mitchell, & G.U.M. Jarvis editors, 1983. Mediterranean-type Ecosystems the Role of Nutrients. Springer-Verlag.
1984	Perth, Australia	Resilience	B. Dell, A.M. Hopkins, & B.B. Lamont editors, 1986. Resilience in Mediterranean-type Ecosystems, Junk, The Hauge.
1987	Montpellier, France	Time Scales & Water Stress	F. di Castri, C. Floret, S. Rambal, & J. Roy editors, 1988. Time Scales & Water Stress. Proceedings of the 5th International Conference on Mediterranean Ecosystems. IUSB, Paris.
1991	Greece	Plant-Animal Interactions	M. Arianoutsou & R. Groves editors, 1994. Plant-animal Interactions in Mediterranean-type Ecosystems, Kluwer, Dordrecht.
1994	Reñaca-Viña del Mar, Chile	Land Use & landscape Disturbance	P.W. Rundel, G. Montenegro, & F.M. Jaksic editors, Landscape Disturbance and Biodiversity in Mediterranean-type Ecosystems, Springer-Verlag, 1998.
1997	San Diego, CA, USA	Global Change & Mediterranean Ecosystems	No general publication.
2000	Stellenbosch, South Africa	Mediterranean-type Ecosystems: Past, Present & Future	Selected papers in various issues of The International Journal of Mediterranean Ecology.